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Engineer





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ENGINEERING FACTS AND FIGURES

FOR 1863.

AN

ANNUAL REGISTER OF PROGRESS IN MECHANICAL
ENGINEERING AND CONSTRUCTION.

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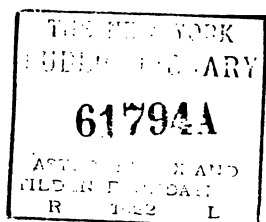
ANDREW BETTS BROWN,

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PREFACE.

It is impossible to over-estimate the importance of the art and science of Engineering as one of the powers which ministers to the material wealth and prosperity of this country. Its followers, by their mechanical genius, and by their patient and painstaking industry, have changed the very face of the material world. Their wondrous working mechanism has almost annihilated time and space,—has bid defiance to the winds and waves,—has clothed a world, and in a thousand ways ministers at once to the comforts and the luxuries of our people. Engineering is pre-eminently a progressive science, and the experience of to-day but helps to improve and extend the labour of to-morrow. Nothing, therefore, could be more interesting than to trace the history of the science in all its departments, and to take note of the feeble way in which, in their earlier times, Engineers stepped forward in the path of progress, contrasting it with their assured mien and firm step in maturer manhood. But unfortunately this history of the art does not exist, and with it the lessons which Engineers of the present day might have learned from that which has long passed over them, are irretrievably lost. It is difficult to say how *far suggestive* these lessons would have been; it

may, at all events, with safety be predicted that they would have been to a very large extent useful. The experience of those who have gone before us in a path of difficulty which their energy and industry have made comparatively easy is invariably valuable: and if its records do not always point out the course to be followed, they are not the less useful if they give warning of the dangers which are to be avoided. The pilot who warns the sailor of the rock performs as good a service as he who shows the safe entrance to the harbour. A complete record then of past experience and practice would have been of immense importance to the Engineering world; and it cannot but be matter of regret to those interested in its sound progress, that that record does not exist. Regrets, however, are useless where regrets are vain, unless, indeed, they urge us to make up the failings of the past by provision for the future. Aiming in this direction—a direction of undoubted utility—the present work has been projected. There is fortunately now no lack of materials existing amongst us with which to fill its pages; they are abundant exceedingly—and out of them we can extract, if we will, matter of immense practical value. But scattered here and there, many of them are out of the reach of numbers of practical men; and it is to bring them within their reach that is the object of our work.

It is not designed to embody the opinions of the Editor; what is wanted, he believes, are opinions of those who, either by their theoretical investigations or by their practical works, are enriching the art and practice of Engineering, and aiding the progress of those works which, whether in *the exquisite accuracy* of minute mechanism, or the power

and grand stability of more imposing machines and structures, are making—as they have already made—the Engineering interest of Great Britain one of the most remarkable features of the age we live in. At the same time the Editor has deemed it not out of place to give here and there remarks of his own bearing on the subjects which may be under discussion. For these he is, therefore, responsible, and he can only claim for them the merit of being derived from practical experience.

In a work treating of so many departments of a many-sided art, a good arrangement of its subjects is obviously of the utmost importance. It is not enough that the Editor gives to his Readers a mass of matter, it is essential also that this matter shall be presented to them in such a way that to any part of it to which reference is desired, reference may be made with the greatest facility. The good arrangement then of the work has been a matter of the most anxious care on the part of the Editor, and he believes that he has succeeded in some degree in securing it.

We have said that the materials for such a work abound. They exist in the numerous periodicals and reviews, devoted, some exclusively, some partially, to the discussion of Engineering subjects, and in the Transactions of Engineering and Scientific Societies; and the vast mass of matter disseminated in this country, is supplemented and rendered still more bulky by the corresponding materials of Foreign Countries, of the North American States, and our own Colonies.

The Editor is aware that there are other publications touching on the same ground, but while gladly acknowledging their *usefulness and the ability with which they are*

conducted, he believes that they do not occupy the same position as that which it is the purpose of his own to take up. Much of their space is taken up by the introduction of matter which, however interesting to some classes of scientific men, is not so to Engineers. To Engineers alone the present work is dedicated, and for them alone its pages are designed. The utmost care shall be taken to make its pages a careful record of the facts of the year; the Editor, therefore, shall be gratified by such suggestions as may be calculated to make it thoroughly complete in all its departments.

In presenting this, the first volume, the Editor has to acknowledge his special obligations to the following Journals published in this country, all of which are conducted with admirable ability, and contain a vast variety of valuable facts and papers. He can only regret that the limited space at his disposal has prevented him from drawing the attention of his readers to other subjects discussed in their pages:—The Engineer; the Mechanics' Magazine; the Practical Mechanics' Journal; the Engineer and Architect's Journal; the Building News; the Builder; the Chemical News; the Scientific American, published at New York; and the Transactions and Reports of the Scientific Societies and Associations.

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ENGINEERING

FACTS AND FIGURES FOR 1863.

DIVISION FIRST.

BOILERS AND VESSELS FOR CONTAINING STEAM AND OTHER HIGHLY-PRESSED ELASTIC FLUIDS.

IN this section of mechanical engineering no decided novelty or great improvement has been introduced during the past year. The manufacture of boilers and other iron structures is so much simplified that, comparatively speaking, little advance has been made in the forms of and the details of manufacture. The "plating," "riveting," and "caulking," may be said to make up the sum of boiler-making. Of course in other boilers, according to design, tubes and other small passages for fire or water are made use of, and consequently involve a different class of workmanship in producing such tubes, and in effectively fitting them to their place in the boiler. Of plating little has transpired during the past year worthy of special notice. Of riveting, however, some improvements have been introduced of late years, such as in machine riveting, hot and cold riveting, &c. On this subject W. H. King, of the United States navy, in his "Practical notes on Steam," says of riveting:—"In the United States there are three mechanical modes of uniting plates together; namely, *machine-riveting*, and *hot* and *cold hand-riveting*. On the seaboard all kinds of boilers are riveted by the two first-named methods, in both of which the rivets are put in hot. West of the Alleghanies, all riveting is done by hand; and at

Pittsburgh, Louisville, and other places, the rivets are driven cold in all places accessible for the purpose.

"For the cold process a superiority is claimed consequent upon the holes being well filled with the body of the rivets; that is, there can be no contraction—hence reduction in the strength and in the rivets' diameters after the workmen cease hammering on the heads. The reverse must be the case when driven hot; for, in cooling, the diameters are reduced by contraction. Moreover, none but the best quality of iron can be used in rivets driven cold; because, if the iron be inferior, it is sure to crack or split through the head, each one being tested by the heading.

"For hot riveting it is claimed that, in cooling, the rivets contract in length, drawing the sheets more closely together, thereby creating adhesion sufficient to add to the strength of the joint. Mr. Clarke, resident engineer of the Britannia-bridge, made some experiments to determine the value of this. Three plates were riveted together by a machine, maintaining a temperature of 900 deg. in the rivets; each outside plate had a circular hole in which the rivets fitted exactly; but in the centre one the hole was oval, or $2\frac{1}{2}$ in. long for a $\frac{7}{8}$ rivet, and the rivet was not allowed to touch either end of this hole. A strain was then put on the centre plate till it began to slide, which it did abruptly. Several trials were made, and the least result was an adhesion equal to $4\frac{1}{2}$ tons with $\frac{7}{8}$ rivets. Mr. Clarke infers from this experiment that, by judicious riveting, the adhesion may in many cases be nearly sufficient to counterbalance the weakening of the plates from punching the holes. In this particular we regard his opinion as an error; for if he had continued the strain on the plate until it parted, or the rivets broke, he would doubtless have found that the total pressure, or breaking strain, would have been 56 per cent. if single-riveted, and 75 per cent. if double-riveted, of the sheet, as fully tested by other experiments. Theoretically, there is a gain from adhesion in hot-riveted joints, but practically this seems to be lost by the contraction of the rivets' diameter, thus making the total or breaking pressure the same.

"In western river boilers, where the pressure of steam used is higher than in any part of the world, no difficulty has ever been experienced from the cold-riveted joints not being closely united and perfectly tight; and as regards strength compared with the

hot-riveted, superiority is claimed by those having cold-riveted boilers in charge.

"In either mode of hand-riveting the rivets can be seriously injured by too much hammering, and in any case by overheating. Due regard should be had to the temperature, and the blows of the hammer should be hard and quick, and not continued longer than necessary to form the head. Machine riveting has the advantage of forming the head at a single blow, and the rapidity with which the work can be performed must always give it preference over all other methods where it can be employed.

"It is to be regretted that no extended set of experiments have ever been made in this country to determine the relative strengths of the different modes of riveting and uniting the sheets of steam-boilers and other iron structures; also to test the relative value of the materials used in this country at the present day; for it must be evident that although the results of European experimenters on iron and steel are of value to us, yet they cannot be regarded as entirely applicable to American constructions, because our iron ores, the temperature of blast of smelting furnaces, and manner of working the metal through the different processes, and the fuel used, all differ in a large degree from those abroad."

According to this authority it seems that cold riveting is much practised in America. We should think, however, that it would be very much more expensive, and, at the same time, unless the iron was unusually good and well annealed, the head would be liable to split at the edges before being properly finished; probably machine riveting would give the best results cold. Several attempts have been made to unite boiler plates by welding, and although the practice has not become general, yet considerable success has attended such operations, and it yet remains for enterprise and capital to bring such a system to a practical issue. The *Mechanics' Magazine* says on this subject:—"The employment of rivets for securing metal sheets or plates together, is of extremely ancient date. The principle must have been obvious to the first workers in iron, and being really susceptible of very little improvement, the art, if such it can be termed, has been handed down from generation to generation without alteration. Almost the only difference between the boiler seam of a century ago, and that of the present day, is found in the use of the

'snap,' for finishing the rivet point. We are not aware of the existence of any very old structures of plate iron which have the rivets so finished. 'Snapping' a rivet only adds to the finish of a joint, but in no way conduces to its strength, and can scarcely be considered in the light of a substantial improvement.

"Until a comparatively recent date, the belief obtained with most engineers that a riveted joint, if the work were properly executed, was superior in strength to the plate itself—an assumed fact which they endeavoured to account for, on the ground that the contraction of the rivet during the process of cooling, bound the two surfaces in contact so closely together, that the friction between them prevented the exertion of much shearing force on the rivets, and compensated for the weakening occasioned by punching the necessary holes near the edges of the plates. The fallacy of these arguments was often demonstrated by the failure of riveted joints while the plates remained intact. Nevertheless, the advocates of the theory held out strongly in support of these views, until Mr. Fairbairn conducted a very valuable series of experiments, which resulted in proving, that the strength of the plate being taken as 100, that of a double-riveted joint will be 70, and that of a single-riveted joint 56. This, be it remembered, with first-rate workmanship. American engineers have tested the real value to be attached to the friction between two surfaces riveted together as in ordinary seams, with the exception that the holes were made oval in the direction of the strain for the purpose of experiment. A very considerable force was required to cause the plates to slip on each other, but this fact did not affect the results in the least. They amply confirmed those given by Mr. Fairbairn. 56 per cent. of the whole strength of the plates which form a steam-boiler is certainly not much to realize with the best workmanship; but as many of our boilers and ships are put together, even this per-centage must be regarded as too high. There are difficulties involved by the nature of the process which the best mechanic can only combat, seldom or never overcome. However accurately two plates may correspond before the holes are punched, that process inevitably distorts them, and occasions a bad fit when subsequently put *together*. The hammering and bending at the edges entailed, is *invariably* injurious to cold plates. Again, the best possible

workmen, with the best machinery, find it out of the question to make all the holes in a long seam correspond. The constant use of the drift is a result certain to follow; and when plates are of inferior quality or very thin, and the holes near the edge, cracks are frequently established from one to the other. The judicious use of the caulking chisel easily conceals the defect, which is none the less serious because it is invisible. Even the drift often fails, however, to secure the entrance of the proper rivet, and one made of lead is the substitute. The best rivets, too, seldom completely fill the holes they occupy. They are seldom or never truly at right angles to the plates, and are often exposed to an enormous strain in drawing plates together where they are badly fitted. We have seen from this cause the heads fly off half a score of 'Best Best' rivets at once in rolling a new boiler from one side of a shed to the other. When we take all these circumstances into consideration, we believe that 46 per cent. of the strength of the plates will pretty accurately represent that of the seams of a very large proportion of our boilers if single-riveted, as most of them are.

"Impressed with the evils of such a system, Mr. Fairbairn introduced the use of iron plates rolled with thickened edges, to compensate for the loss of strength entailed by the holes. The objection to their employment he sums up in a few words:— 'At the commencement of the trade in iron ship-building I patented an arrangement for rolling plates with thick edges, and employed plates so prepared to some extent; but the cost of production at that time and some difficulties in their employment prevented their general use.' The whole principle, indeed, of riveting boilers is so erroneous that it is scarcely susceptible of much improvement.

"Within the last few years attempts have been made, with more or less success, to unite the plates of boilers, ships, &c., by welding, instead of riveting. The first English patent, apparently, which touches on the subject, was taken out in 1825, by a Mr. Whitehouse, for welding tubes 'by circumferential pressure without a mandril.' The next was by Stratton in 1844, for welding plates *to form hollow ribs* for ships; which the patentee *proposed to effect, by rolling strips of metal concave, with flanges; which strips of metal being placed with their concave sides to-*

wards each other, and the flanges being welded together, formed tubular ribs for ships, &c., as proposed. Some of the first locomotives built by Bury had welded joints. A patent was obtained by William Bertram in 1854, which seems to be the first proposing the application of a gas flame urged by a blast, to the heating of plates to be welded. The patentee scarfed the edges of the plates, placed them together, and directed two pure gas flames, obtained by the combustion of coal or coke in suitable furnaces, on either side of them until raised to a welding heat, when they might be united by pressure or hammering. William Morgan patented nearly the same process in January 1856. Russell, in 1859, proposed to employ a framing with two arms; the lower one supporting a convex tool or anvil, which going inside of, aided in sustaining the boiler being welded, its weight chiefly resting on rollers, which were fixed near the ground. The upper arm carried another tool or hammer with a convex face, which was traversed up and down in vertical slides, on much the same principle as that involved in Rider's forging machine. Two portable gas furnaces were provided, one within, the other outside the boiler, to raise the plates to the welding point. The whole apparatus appears to have been simple and well-contrived; but from some cause it has not come into general use. Alleyne, in December 1859, patented an invention for welding boiler plates, by the intervention of a 'glut,' which consisted of a bar of iron, with a cross section resembling . The edges of the plates to be welded were inserted into the grooves, which aided in retaining them in their place. The whole was then exposed to suitable gas jets, and raised to a welding heat and united by the pressure of rollers or by the hammer. The 'glut' was intended to prevent the oxidation of the plates; a needless precaution, as flame is incapable of oxidating a metal surface. Still there are certain matters of practical convenience, which incline us to the belief that the principle involved in this patent may be occasionally employed with advantage, particularly in welding transverse seams in circular boiler shells."

The subject of tubes is one of considerable importance, and forms a very serious item in the expenditure of the locomotive department of railways. Brass tubes have hitherto been almost

exclusively used, most railways considering them in the end more economical than iron ones, from the fact of their being generally able to "piece" such tubes by brazing, and thus put them in a second time, at the same time the metal being, when done, valuable for brasses, &c. Iron tubes, of course, when once taken out, are useless, and, as old metal, comparatively worthless. On this subject the *Mechanics' Magazine* says:—"It is well known that brass boiler tubes are generally adopted in England in preference to those of iron; nevertheless, some railway companies use iron tubes to a great extent. A difference of opinion still exists as to the comparative advantages of the two kinds; a series of experiments and a record of actual results are the only means to get at the truth of such matters. For some time the Prussian government railways have been using wrought-iron boiler tubes for their locomotive engines. Results extending over several years allow us to believe that this kind of tubing is at least equal in strength and duration to brass tubes; while for locomotives, iron tubes are superior in economy with regard to first cost, repairs, and renewal. It is generally found that they are less subject to split in the direction of their axes, and thus cause leakages, than brass tubes. No case has yet occurred of the explosion of one of these pipes; an accident which is not unfrequent with brass tubes. Wrought-iron tubing can also be fixed without the inside ferrules that always somewhat diminish the useful heating surface. Being of the same metal as most of the other parts of the boiler, they are subject to a similar amount of expansion and contraction by heat, and the different parts are thus better united together. The objections that have been raised against wrought-iron tubes consist in their favouring the increase of incrustation in the boiler, in being fixed with greater difficulty to the tube plates, and in forming leaky joints. With regard to the last objection, that of liability to leakages at the joints, it may be stated that this fault does not seem to be inherent to iron tubes; at least when the fire-box and smoke-box tube-plates are new, the holes are exactly drilled, and the caulking is properly done. Wrought-iron tubes, when first introduced, were naturally employed to replace those of copper or brass, and thus the holes in which they were to be fixed lost their circular shape and regularity in consequence of repairs and

previous working. Copper and brass tubes, possessing more malleability, suited themselves to any irregularities, and could form tight joints, being in this respect superior to iron tubing. Generally speaking, it is to be remarked that iron tubes often require to be replaced when the fire-box and smoke-box tube-plates are in a bad state; the most frequent cause being leakages at the joints; and when iron tubes once become leaky, their ends get soon wasted away, and cannot afterwards be depended upon. The *Zeitschrift für Bauwesen* gives the following comparative results as to the use of this description of tubing. The engine No. 23, on the Aix-la-Chapelle to Dusseldorf line, was fitted with iron tubes since the year 1857; and, up to the latter end of the year 1861, the engine had run 78,747 kilometres without any accident to her tubes. On several other German lines iron tubes have been used almost exclusively since 1857-8.

"Iron tubing has been used on the Westphalian net of lines since 1857. During that year six engines were made with iron tubes; and in order to institute an exact comparison as to the relative advantages of the two kinds of tubing; a few months later, six other engines were made with copper tubes. By the month of October 1861, 214 of the 978 tubes (21.9 per cent.) contained in the first six engines had been changed. The tubes had been on an average 28 months in use, and had run 69,500 kilometres. The six locomotives, taken together, had travelled in all 295,380 kilometres, but one of the six had travelled 98,000 kilometres, which accounts for the average run of the tubing being nearly 70,000 kilometres, while the average distance run by the engines experimented with is only 50,000 kilometres. It may be taken for granted that the last engine could have run a further distance of 50,000 kilometres without using up her tubes.

"In the six engines built with copper tubing there were 937 tubes; by the end of the year, 1861, 348 of these tubes had to be changed, (or 37 per cent.) after an average duration equal to 23 months, and an average run of 48,480 kilometres. The total mileage of the locomotives with copper tubing amounts to 344,415 kilometres, while that of the engine the most used equals 103,670 kilometres; and it was then calculated that the tubing would last for a further distance of 50,000 kilometres.

If the iron tubes, instead of having only run 295,000 kilometres, had run 345,000 kilometres, like the brass tubes, the proportion of 21·9 per cent. of their renewal would have been raised

$$\text{to } \frac{345 \times 21.9}{295} = 25.6;$$

that is to say, 25·6 per cent. of the iron tubing would have to be replaced. This must be compared with the average of 37·1 per cent. given by the brass tubing. The Prussian line on which iron tubes are the most extensively employed, is the Niederschlesisch Markisch Railway; 30 locomotives are used for the traffic on that line, and are furnished with a total number of 4,503 iron tubes. Only 1·31 per cent. of these tubes required changing in 1860.

"According to Despretz, the conducting powers of iron and copper are respectively as the numbers 374 and 898, gold being taken at 1,000. These powers, however, are subject to great variation under the influence of practical conditions. The numbers cited above have been obtained when the surfaces of the metals were clean and bright, and were not subject to those practical influences that often completely modify the expectations formed by calculation. In the year 1857, Mr. Tosh, of Maryport, read before the Institution of Mechanical Engineers a short account of some experiments he had carried out in order to ascertain the relative conducting powers of brass and iron tubes. He used two vertical boilers of equal dimensions, 6 in. diameter and 2 ft. long, with a single tube in the middle of each, 2 in. external diameter and No. 14 wire gauze thickness, of brass and iron respectively. 'The two boilers were filled with water of the same quality and of the same temperature, and alternately placed upon a stand in the same position over a gas flame; they were each exposed to the action of the gas for the same length of time, which was equivalent to the same quantity of fuel being consumed in each case; and the height of water was carefully gauged after each experiment as soon as ebullition had ceased.' Great care was taken to prevent any change in the pressure of the gas. According to Mr. Tosh's experiments, the evaporating power of brass is to that of iron as 125 to 100; or brass will evaporate about 25 per cent. more water than iron, with the same quantity of fuel. Experiments were also made with brass

and copper tubes, and copper was found to be as superior to brass as brass to iron. The relative evaporating powers of copper and iron were found to be as 156 to 100, and, according to this result, copper should evaporate 56 per cent. more water than iron, using an equal amount of fuel. In the discussion that ensued, Mr. Tosh said that the consumption of gas had not been regulated by a meter, but a uniform pressure had been attained by applying to the authorities of the gas works.

"Professor Rankine said that a number of experiments had been tried many years ago with experimental boilers of iron and copper of different thicknesses. These experiments were tried by Mr. James R. Napier, and he heated the boilers over the same gas flame, but found only a slight difference in *evaporating* power of about 1-20th or 1-30th to the advantage of the copper. Professor Rankine stated that in all experiments of the kind the state of the heating surface was an important matter; as to whether it was smooth or rough, either perfectly clean or encrusted to any great extent. The effective evaporating result, or transmission of heat through metal, as was also stated by Mr. Rankine, evidently depends on three properties:—'1st, the resistance of the first surface to absorption of heat from the heated air and gases; 2d, the resistance of the internal particles of the metal to the conduction of heat; and 3d, the resistance of the second surface to giving off heat to the water; those three properties were not possessed in the same proportion by different bodies; the resistance to internal conduction was less in copper than in iron, but the resistance of the surface was greater in copper.' Mr. Rankine recalled to the minds of the members of the Institution the well-known experiments on the transmission of heat, made by Mons. Peclet, who found that metals all conducted pretty much the same when their surfaces were dull. It is evident that, in the experiments we have cited, the tubing was scarcely under the same practical conditions as in a locomotive boiler. Mr. Siemens alluded to another difference, owing to any variation of the draught on the gas flame through either of the tubes carrying off the heat with greater speed; 'the brass tubes might also gain an advantage from their smoother surface causing less adhesion of the minute bubbles of steam during slow ebullition, though that circumstance would not apply in rapid ebulli-

tion.' It would thus appear that iron tubes are practically equal in heat-transmitting powers to brass tubes. As regards duration, they actually appear to be superior to brass tubes, especially when any leakages are avoided by careful attention and workmanship."

In the manufacture of tubes great improvement has been made, the solid drawing of brass tubes being an important one. Iron tubes, however, are still made by lap welding, and therefore have not the solidity of brass tubes. Several patents have of late been taken out in connection with solid cold-drawn tubes, gun barrels, &c., and from experiments made, seem to promise the production of wrought iron boiler tubes, cold and solid drawn, and of greatly increased strength, so that the same thickness will not be required. On this subject the *Mining Journal* gives the following description of a company forming for the purpose of introducing such tubes:

"The many purposes to which cheap and reliable iron and steel tubes could be applied are so well known that it is quite unnecessary to refer to them—boiler-tubes, hollow axles, hydraulic pipes, hollow taps, surface condensers, piston-rods, steel collars, and gas piping, being but a few of the articles for which they could be substituted for those now employed. Such being the case, it is concluded that an invention that admits of tubes of almost any length and diameter being drawn from the cold metal, and of a quality capable of being used even for gun barrels, could not fail to prove remunerative to those developing it; a company has, therefore, been incorporated under the Companies Act, 1862, with limited liability—the Solid-drawn Iron and Steel Tube Company—with a capital of £150,000, in shares of £5 each, for purchasing and developing certain patents for the manufacture of iron and steel tubes without join or weld, in a rapid and most economical manner, and of any shape, size, and length within the ordinary limits of mechanical force.

"The advantages claimed for the invention are really marvellous. The tubes being drawn cold, and without any action of fire, an enormous saving results in the metal; thus, by this process, two Enfield rifle barrels of the standard size, weight, and strength, can be drawn from the piece of metal now consumed in the manufacture of one barrel, while the process is so inexpen-

sive that an Enfield rifle barrel of the present kind can be produced for less than one-half the present cost, and a steel barrel of like length and dimensions for the present price of iron ones. The proofs to which the new cold-drawn steel gun barrels and tubes have been submitted establish, beyond doubt, the fact that the metal employed is of excellent quality, and that the mode of manufacture is thoroughly applicable to all the purposes to which it has been applied. The privileges to be purchased by the company include not only the processes for manufacturing the tubes, but the monopoly of the peculiar steel from which those tubes can be made, and which is superior to any at present known to commerce. It is intended, in the first instance, to erect a small factory to prove the invention, and to grant licenses to manufacturers upon terms that will aid rather than conflict with existing interests.

"The terms upon which the patentees agree to transfer to the company all their patents for the United Kingdom is £10,000 cash, and £20,000 and a royalty upon the dividends paid by the company during the continuance of the patents; but, as a proof of their confidence in the eventual success of the patent they agree to forego all payment until after the satisfactory trial of the machinery in London, and to take neither dividend nor royalty until 10 per cent. has been paid on the first issue of £75,000 of capital. The severity of the proofs to which the gun-barrels have been put leave no doubt whatever as to the reliance which can be placed upon the invention.—At Paris results were obtained which secured the unequivocal approbation of the military engineers and gunsmiths who assisted at the experiments; at Birmingham the barrels stood more than double the ordinary proof charge without being affected; and at the London Proof House the tests were equally satisfactory. The direction of the company comprises the names of gentlemen well known in connection with commercial affairs; and, as no payment beyond the deposit of 10s. per share is to be made until the value of the invention is proved, considerable inducements are offered to capitalists."

In the forms of boilers considerable advance has been made *during the year*. These have principally taken the direction of *lightness and rapid generation of steam*, in connection with the

requirements of steam fire engines; of such boilers, see description of such engines. Of the importance of having light boilers, a minimum water space, &c., much may be said, especially in connection with marine engineering, the saving of dead weight, the reduction of that quantity of explosive water at a temperature of 300° and upwards, are all items of considerable improvement where they can be effected. The Mechanics' Magazine on this subject observes:—"The actual quantity of boiling water required for the safe development of a given amount of steam-power in a certain time, is a question which has never yet been decided, and most probably never will. So long as the heated plates of a flue or a fire-box are in contact with a depth of fluid sufficient to absorb all the heat imparted to them, it seems likely enough that every necessary purpose is fulfilled; but what the exact quantity required for the attainment of this object is, must remain for the present, at least, a doubtful point, depending not only on the description of plates employed, and the quality of the water used, but on the intensity of the draft, the quality of the fuel, and many other points of detail, too various and uncertain to permit a very close approach to theoretical limits in practice. The ambiguity of the question, or its answer, does not, however, lessen their importance. The largest field for the employment of steam power is found in our naval and mercantile marine, and there at least does the question of the reduction of every portion of the machinery, to the smallest possible limit of weight, assume the greatest importance; and very little reflection is required to convince us that that form of steam generator is most suitable for marine purposes, which will work safely and economically with the least possible quantity of water.

"Whatever improvements may have taken place in our marine engines, it is certain that they have been few enough in the marine boiler. Since the introduction of tube flues, little or no alteration has taken place in the general principles of its construction, or in those matters of detail on which its suitability to its position depends. It still exists in all the clumsy majesty of size, much as it did half a century ago. Alterations in its internal arrangements have been few; in its external form still fewer; and for the sake of securing some important advantages, our engineers have been content to sacrifice many things equally

valuable. As a result, we still find our ships encumbered with huge structures of plate iron, costly to make, difficult to repair, and of the very worst possible form for fulfilling one at least, of the legitimate purposes of a steam generator, that of sustaining a heavy pressure exerted within it. When anything above a nominal pressure is required, the engineer is compelled to resort to the use of stays to such an extent, that the interior of the boiler is rendered almost inaccessible for repairs or examination, while its weight and cost are seriously increased. Nor are these the least evils induced by its defective form. From the peculiar arrangement of uptakes and ashpits, stokeholes are, as a rule, almost unfit for the existence of human beings within them, the last refinements of ventilation being necessary to render them endurable when situated at the bottom of a large vessel; man-of-war or merchantman. The worst defect of all is found in the fact, that these boilers carry tons of water, to accomplish results attained as easily in other situations, by cwts. of the liquid.

"It is pretty certain that a given area of heating surface will produce nearly similar quantities of steam, by the combustion of equal weights of fuel, whether it is covered with water to the depth of an inch or a foot; whether the boiler, in fact, contains a gallon or a hogshead; a cwt. or 10 tons. Certain rules are, it is true, laid down by James Watt and others, for determining the proper area of evaporating surface, &c., which a well-proportioned boiler should possess. Such rules are, however, simply absurd in a general sense; the heating surface with which the water is in actual contact being, of course, the most important measure of boiler horse-power. The cubic contents of the space filled with fluid, that occupied by steam, and the water surface exposed, are merely matters of detail, which can only affect the quality of the steam supplied to the engines, and have little or nothing to do with its quantity; save in one respect, which is simply, that the reduction of the quantity of water contained in a boiler, is always accompanied by an increase in the economical production of steam, from the very obvious reason that the agitation of many tons of any liquid by the process of ebullition, must waste power to a very considerable extent; consequently, any reduction in its quantity is attended by a proportionate *diminution of this waste*. Most engineers are well aware of this

fact. Thus, Mr. Armstrong states, in his valuable work on steam boilers, that he has found considerable advantage accrue from the introduction of hard-baked bricks, within the water-space in large waggon and cylindrical boilers.

"There are, however, other considerations besides questions of economy or convenience, which must regulate the amount of water-space allowed in a generator. We usually find that the extent and form of the heating surface is its real measure, far more than anything else. And these again depend, on ship-board, in a great degree on external agencies, which have nothing whatever to do with engine or boiler, except so far as they govern their shape and size. The weight of a boiler does not, however, depend on the greater or lesser extent of water-space which it affords, but on the heating-surface—in well-constructed boilers at least whose external superficies bear a very small proportion to the surface exposed to the direct action of the heat in the fire-box or flues. No matter what form that surface may assume, the metal of which it is composed should form a large proportion of that employed in the construction of the boiler, and must influence its weight more than any other consideration. We thus meet with generators, every now and then, which develop as much useful effect with a few gallons of water as ordinary boilers do with tons. But these generators are never light in an equal proportion; and the ardent pursuit after a boiler, light in this sense, is really a mere waste of talent, time, and money. We are, however, speaking just now more particularly of the marine boiler; and although we do not believe that its weight, when empty, can be materially reduced by any change in form or construction, we nevertheless feel certain that its weight—when taken as a whole, with its contained water, as a distinct apparatus for the production of power—is excessive, and that its reduction to reasonable limits should be one of the first objects of the engineer.

"That this desirable end will ever be attained while we retain the use of flues returning over the fire-boxes, we very much doubt, because this arrangement of heating surface requires the employment of an immense quantity of water, not because it is in any way necessary to the effectual absorption of the heat produced in the furnaces; nor yet because dry steam cannot be

supplied without it, but solely because large spaces are left within the boiler which cannot be so conveniently occupied by anything else. Thus, we find a distance of 8 in. or 12 in. at least, left between the crowns of the furnaces and the lowest rows of tubes, in order that a man may find access to the fire-boxes when they require repairs. 3 in. of water over a fire-box are ample under other arrangements; and we know that the excessive space now provided easily accommodates many tons of dead weight, which is of no possible service. Few engineers who have gone into the subject in a proper spirit, will be disposed to assert that a boiler can be constructed on correct principles, which entails the necessity of carrying about, and heating, tons of water in no wise essential to the working of the propelling machinery; or that it can possess any compensating advantages which preclude the idea of its superseding by generators of a different form.

"We must remember that this question of marine boiler improvement daily presents itself to our notice in a more important light. However suitable the present normal form may be for pressures below 15 lb. or 20 lb., it signally fails when that pressure is exceeded. No amount of staying can possibly convert it then into a safe and economical generator. The growing tendency to employ high-pressure steam, the active competition in marine-engine building, render its remodelling a question of the utmost importance—a question which should neither be slurred over nor treated with haste and carelessness. We are heretics enough to believe that it would have been better for the marine-engine at least, that a condenser had never been invented at the time it was. The possibility of attaining a paltry vacuum of 10 lb. or 12 lb. to the inch, has been the greatest bar to real progress the steam-engine ever encountered. Had no such thing been attainable, we would long since have had propelling machinery as light and as simple at sea as we have on our railways, where a vacuum was and is unattainable. At sea, that which should have been employed as a good servant has become a bad master, to whom space, money, and every other consideration are given up, in order to obtain results, the advantage of which is at best quite inadequate to the sacrifices made.

"That the present form of marine boiler will be much longer

retained, we doubt; that it will be replaced by something much better, we believe. Indeed, unless we wilfully shut our eyes to the light and experience afforded us by locomotive engineering, we can scarcely go astray. The boiler of the locomotive is, after all, the best which has ever been designed for the development of vast power within a limited space, and it requires but trifling modification to render it as suitable for the purposes of propulsion at sea as on land. The reduction of weight and space, the economy of fuel, the facility for carrying the highest pressures with ease and safety, which its use would secure, are advantages sufficiently important to outweigh all considerations of extra expense even if they existed. What we want on ship-board is simplicity, not complication; and it is much better that we should avail ourselves of what is known and tried, rather than introduce novelties of which past experience tells us nothing."

Perhaps the best guide to improvement and perfection in any department of engineering, is the careful observation of all defects or failures connected with such work. In boilers, although considerable mystery attaches itself to their failures or explosions, yet most of them can be traced to definite causes, and therefore are exceedingly useful in drawing attention to those defects in manufacture or management which may induce deterioration or consequent failure. The experience of the MANCHESTER STEAM BOILER ASSOCIATION in this way is very valuable, and we therefore give a full extract from the annual report for the year 1862, of the chief engineer, Mr. L. E. Fletcher. In this report, the engineer says:

"Before entering upon the detailed consideration of the defects detected on the examinations, it may be stated, that a gradual improvement is found to be going on in the general character of the boilers under inspection, as well as in the arrangements of their fittings. The new constructions are marked with more simplicity and accessibility of parts and fittings, and can be more readily attended to by the engineer in charge, as well as more satisfactorily examined by the inspector, and entail much less anxiety in answering for their safety. Notwithstanding this general improvement, however, the defects ascertained this year are more numerous than those of last year; this may be accounted for by the increased number of 'thorough' examina-

tions previously referred to, which have revealed defects otherwise unknown; an additional illustration of their importance.

"The defects discovered in boilers are mainly of two distinct classes—one relating to their construction, and the other to their condition.

"Under the first head, namely, that of construction, 196 recommendations have been made, which are as follow:—

"In 153 boilers the internal flue-tubes have been recommended to be strengthened by hooping.

"In 18 boilers the shells have been recommended to be strengthened at the steam dome by stays of angle iron, &c.

"In 9 boilers the shells have been recommended to be strengthened at the ends.

"In 16 boilers the load on the safety-valves has been recommended to be reduced.

"The following are those defects appertaining to the second head—namely, that of condition. Of these, 85, which are as follows, were considered dangerous:—fractures of plates and angle irons, 13; blistered plate, 1; furnaces out of shape, 12; corrosion, 37; defective safety-valves, 5; defective water-gauges, 9; defective feed apparatus, 1; defective blow-out apparatus, 7.

"Others not actually dangerous, but still unsatisfactory, are as follows:—fracture, 60; blistered plates, 19; furnaces out of shape, 33; corrosion, 270; safety-valves irregularly loaded and otherwise out of order, 94; water-gauges out of order, 135; pressure-gauges out of order, 76; feed apparatus out of order, 35; blow-off apparatus out of order, 224; fusible plugs out of order, 49; also two instances of deficiency of water.

"It may be added that many of the above defects were observed at visits made early in the year, and since that time many of them have been repaired.

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"One of the most fruitful sources of fracture in boilers is the unequal expansion and contraction of their different parts, on account of the various temperatures, which are caused in many cases, though not in all, by imperfect circulation of the water.

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"It may, therefore, briefly be stated that grooving still continues to manifest itself in double-flued boilers at the tube angle irons and end plates, more especially at the furnace mouth; and is more active in proportion as the end plates are rigidly stayed. In no class of boiler, however, is this action found to be so destructive as that in which the furnace tubes are brought so close together; that there is not room for the angle iron at either end of the flue to be carried completely round them; and is, therefore, supplemented by what is called a 'saddle-plate,' which, with its complement of the two partial angle iron hoops, forms a 'spectacle-piece.' These 'saddle-pieces' are found to groove so deeply that in some cases the whole thickness of the plate becomes eaten through. There is no satisfactory cure for this but their entire removal, and the tapering down of the flue-tubes at the mouth, so as to increase the intermediate space.

"Channelling at the transverse seams at the bottom of the shell of internally fired boilers, is still met with. It generally is discovered in the bottom external flue, on the outside of the plate immediately at the edge of the overlap, being deepest at the centre or 'keel' line, and dying out in about 15 inches on each side, but very frequently in much less. In one instance, however, it was found on the internal surface of the plate, and to be situated as high as the side wall on which the boiler was set.

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"On the whole a gradual improvement, both with regard to channelling at the bottom seams, and grooving at the end plates and angle irons, is taking place in the boilers under inspection. This improvement is due, with regard to the former, to the more general adoption of means for heating the feed water, as well as to the boilers being now more frequently set, so that the heat from the furnace flues passes immediately under the bottom, and then lastly along the sides, by which means the circulation of the water is improved; while, with regard to the latter, the improvement is due to the fact of the end plates being now less rigidly stayed, and thus, as has been stated in previous reports, having room to 'breathe.'

"*Boilers with two furnaces running into a single oval flue,*

containing a number of vertical water tubes, have the advantage of a more rapid circulation of the water, which is decidedly calculated to prevent both transverse channelling at the ring seams and grooving at the angle irons. There are, however, but a small number of these boilers under inspection, in proportion to those of the double-flued class; but, as far as observation has been made, they certainly appear to compare favourably, on the above points, with their competitors. Water tubes have also been added in a few cases to ordinary double-flued boilers, being fixed behind the fire-bridge with a view to promote circulation, while, with the same object, a new boiler has lately been brought out, in which water pockets or mid-feathers at varying angles are fixed in the flue-tube, with a view of securing it against collapse, and at the same time promoting circulation of the water.

"Other cases of fracture have occurred from fixing angle iron strengthening hoops to flues in an improper manner. This has been so fully gone into in the printed abstract of the monthly report for June last, and which was circulated amongst the members, that nothing need now be added beyond stating that several additional cases have since been met with of plates at the crowns of furnace tubes becoming burnt and cracked, when the thimbles or ferrules between the plates and angle iron hoops, explained in the above report, have been omitted.

"Other cases, again, of fracture, have been caused by the flue-tubes and shell being bound together by a cross stay in the middle of their length, when, from the unequal expansion of the two, one has injured the other.

"One case of fracture has been met with in an externally fired boiler, which occurred at one of the transverse seams of rivets, from the sudden cooling of the plates, by the too hasty introduction of a quantity of cold water immediately after blowing out, while very similar injury has arisen at the transverse seams over the furnaces in other externally fired boilers when in work, and, in addition, several of their plates have both bulged and blistered. Boilers externally heated by the flames passing off from iron furnaces have been found to be specially liable to start at the seams, and crack at the rivet holes, at the point where the flame impinges."

"A boiler with two internal furnaces, as well as an external one beneath it, added with a view to promote circulation of the water, was found to bulge in the plate of the external shell over the fire, while the internal furnace tubes remained uninjured. It is thought that this boiler, from the fact of its combining within itself the two classes of firing, viz., internal and external, affords an apt opportunity of comparing the merits of the two systems, while the result just recorded is fully borne out by a more extended observation of other boilers.

BLISTERED PLATES.

"This subject has been somewhat anticipated under the previous heading, and it will now, therefore, be only necessary to point out, that the fact of plates, by good makers, being liable to blister unawares, and which previous examination evidently fails to detect, shows the importance of not hazarding an explosion upon their soundness. Thus the strength of no unassisted plate, exposed to the action of the fire, should be relied on; and, consequently, it becomes most desirable that furnaces should, in every instance, be stayed either by flanged seams, or with hoops of angle iron, T-iron, or other advantageous form.

FURNACES OUT OF SHAPE.

"The general causes of shortness of water, from which overheating and injury to the furnace crowns ensue, are found to be as follows:—

1. The direct neglect by the engine-tenter of the feed apparatus, which is too obvious to need remark, and too glaringly careless to be otherwise than exceptional.

2. False indication of the glass water-gauges.

3. Loss of water at night on account of leakage of the blow-out apparatus, sometimes from its being carelessly and imperfectly closed.

4. The lighting of fires by night watchmen, and others, without any water in the boiler.

5. Blowing the water out of the boiler with the fire still left in it.

"An efficient low water safety valve, which would—on the sinking of the water below its proper level—relieve the pressure

of the steam, would evidently save the furnaces under some of the above circumstances, though not under all.

"It should be added, that some furnaces are out of shape from their first construction, being found on actual measurement to be as much so as one or two inches, merely from careless workmanship, which passes unobserved until detected on inspection. This inaccuracy considerably weakens the flues, especially when the major axis is horizontal, since the natural tendency of all furnace tubes is to collapse vertically.

CORROSION.

"Corrosion is found to be going on in all boilers more or less, and it will be seen that the greatest number of dangerous defects in the preceding list are to be found under this head. A few instances may be given. In one case, a boiler set upon a mid-feather wall, 15 in. thick, had a channel eaten right along it about 8 in. wide, which ran down the centre of the seating, while the plate at the edges of the brickwork appeared quite sound, and the danger consequently passed for some time unsuspected. In a second instance, with a mid-feather 2 ft. wide, the plate was found to be eaten almost through from nearly one end of the boiler to the other; while in a third, where lime had been allowed to come in contact with the boiler at the mid-feather, the plate was completely pulverized, and could be carried away in handfuls. In a fourth case, a vertical tubular boiler had been placed close to a wall, one part being in actual contact. Damp in the brickwork set up corrosive action in the plate, which, being concealed by the position, went on undetected until the metal was completely eaten through, and a piece blown out by the pressure of the steam. The original plating of the boiler was thick, the pressure low, and the corrosive action local, only affecting a surface of about 12 in. square, so that the rent did not extend.

"A fruitful source of corrosion is found in the leakage of blow-out pipes at their attachment to the shell, while in some cases the pipes themselves are fractured, and continue so for some time unawares, the leakage meanwhile playing on the bottom plate, from which corrosion necessarily ensues.

"Examples of corrosion might be multiplied indefinitely;

enough, however, has been said to show the importance of having all parts of the boiler accessible to examination, the flues sufficiently capacious, and the seatings as narrow as possible, and also of having the brickwork removed occasionally, at all events in places, so as to ascertain the condition of the plates, since to conclude that the parts concealed are in the same condition as those in view, has been found in practice to be fallacious.

"The examples of corrosion, previously referred to, have all been external, and caused in every case by moisture, arising either from leakage or damp in the flue. Internal corrosion is not generally so dangerous, and arises from acidity in the water. Many members are now using carbonate of soda, and all those who do so speak highly of it. Even the Manchester town's water is improved by the introduction of a slight quantity. This water is not found to be dangerously corrosive, but to speckle the plates over minute indentations, in some cases depositing small scales, like miniature flattened walnuts, about three-quarters of an inch in diameter, and one-eighth of an inch thick. These, on being severed from the plate, leave behind them shallow prints on its surface. One firm, having several 50-horse power boilers, and which are fed with Manchester town's water, uses half a pound of soda in each per diem, and finds this quantity sufficient to neutralize the acidity.

DEFECTIVE SAFETY VALVES.

"Reckless or even careless overloading is now seldom if ever met with in the boilers under inspection, though some cases have come under notice of most defective arrangements in new boilers, the safety-valves being placed on the steam-pipes instead of directly on the shell, so that the communication between them was contingent upon the junction valve being open.

"Many safety-valves are found improperly loaded, that is, insecurely so, and with loose irregular weights. Importance is attached to safety-valve levers being loaded, with but a single suitably-adjusted weight at their end.

"The attachment of internal loading to dead-weight safety-valves has, in some cases, been found most insecure. This is a point, from the concealment of the weights and links within the boiler *which is likely to escape attention*, though serious scalding woul

ensue in a confined boiler-house in case of the valves suddenly breaking loose. Of internally loaded dead-weight valves, those are the safest which are boxed-in and fitted with a hand-lifting lever, and a discharge pipe for the waste steam.

WATER GAUGES.

"The recommendation previously given to fix duplicate water gauges to every boiler, and to have the passage in the necks as large as possible, can only be repeated, in the present instance, with the additional force which another year's inspection gives, and many furnace crowns would have been saved by the timely adoption of these simple precautions. The taps of glass water-gauges are almost always found to leak; this can be greatly remedied by having them fitted with nut-glands packed with a little cotton, while the grit, which so soon cuts away the plugs, would be much lessened by the adoption of surface blowing-out.

PRESSURE GAUGES.

"All the pressure gauges fixed to the boilers under inspection are checked by a standard indicator at each of the inspector's visits, provided that the boilers are fitted with the necessary tap. Thus the accuracy of most of the pressure gauges passes constantly under review.

"Generally, they are found to indicate too high a pressure, but, in some cases, as much as from ten to fifteen pounds too little; the first error leading to their being disregarded, and the second to actual excess.

"The pressure gauges under inspection are, with but a few exceptions, of four classes, namely, the natural mercurial column gauge; the mercurial differential gauge; the dial gauge; and the compressed air gauge.

"The natural mercurial column gauge stands first upon the list for accuracy, as its simple and direct construction would indicate.

"The differential mercurial gauge is of inverted syphon construction, the short leg being of larger diameter than the long one, and thus the mercury has less travel in the former than in the latter. The indications of pressure are read off from the *short leg*, which considerably reduces the length of the index

scale of pounds, and those of the best class of this gauge are very legible. In one class of differential gauge, however, the mercury enters the glass indication tube, which becomes very much discoloured in consequence, and, in some cases, quite opaque; while, at the same time, the glass stands off so far from the index face, that it can only be read accurately when the eye is placed on a level with the upper surface of the mercurial column. In another class of this differential gauge the mercury does not enter the glass tube at all, but the pressure is indicated by a floating pointer, so that no discolouration of the glass takes place, and the gauge is always legible.

"Dial gauges are very compact, and can be fixed directly in front of the boiler, just in sight; while those of the best class are very legible; care should be taken, however, not to fix them too near the boiler face, or else to put a piece of wood between the two so as to prevent their becoming heated, or otherwise their indications will be affected.

"The compressed air gauge, in which a syphon column of mercury, as a piston, acts upon an air cushion, is found to be universally incorrect, and is quite unworthy of confidence.

"In conclusion, while the natural mercurial column gauge must be allowed to stand the highest for abstract accuracy, yet the best description of the mercurial differential column gauge, as well as that of the dial gauge, are but slightly inferior to it practically, and are more easily read; while the dial stands pre-eminent for compactness, especially at high pressures, which becomes of importance in a long series of boilers, when each is fitted, as it is always desirable should be the case, with its own independent gauge.

DEFECTIVE BLOW-OUT APPARATUS.

"It has already been stated, under the head of 'Corrosion,' how much injury is frequently done to the bottom plates of boilers by defective joints of the blow-out pipe; to remedy which, a short block should be riveted to the boiler, and the pipe bolted to it instead of direct to the shell. These pipes, which are generally of elbow-shape, should not be bound by the brick-work, since the settlement of the boiler is apt to strain them, and cases have occurred in which they have been fractured in conse-

quence. From this, in one instance, considerable corrosion ensued ; and in another, not under the inspection of this association, in which the fracture was sudden and complete, scalding resulted to two or three persons.

"Many blow-out taps are dangerous to use for want of suitable discharge pipes to carry off the waste water, and, in some boilers, the water spaces have been found to be completely choked with sediment, from neglect of the most simple precautions with regard to the use of the blow-out apparatus. This subject has been so constantly alluded to, that repetition would be tedious, though, perhaps, hardly unnecessary ; it will, therefore, only be added that brass gland taps, recommended in previous reports, are still found to give satisfaction, and to be more certain in their action than either sluice or mushroom valves.

INCRUSTATION.

"Some advance has been made during the past year in the prevention and removal of incrustation, although much yet remains to be done. It is too frequently concluded that incrustation and corrosion are not to be found in the same boiler, and that the plates beneath the scale are protected. Such, however, is by no means found to be universally the case, and frequently, on removing the scale, grooving, or other evidence of corrosion, is discovered on the surface of the plate beneath it. An inspection of a boiler, therefore, coated with incrustation, must always be unsatisfactory ; not to mention the injury to the boiler itself, as well as the loss of heat that results from it.

"The remedy adopted for this evil, in marine boilers, namely, 'surface blowing-out,' has been during the past year frequently brought before the attention of the members, and a drawing made of a simple un-patented arrangement, and placed at their disposal. A very considerable number have availed themselves of this, while as many of the manufacturing engineers as have wished to do so have furnished themselves with copies. In consequence of this, several of these scum pipes have been applied, the exact number is not known, but one firm among others may be mentioned, who have fixed one of these scum pipes to each of their nine boilers, and with the most satisfactory results.

"This is not, however, the only description of scum pipe adopted. The subject of 'surface blowing-out' has been taken up by others, and two varieties of apparatus patented, and somewhat generally introduced. It is thought that this diversity will rather prove of advantage than otherwise; and now that the general principle of 'surface blowing-out' has been called attention to, the more individual ingenuity is directed to the details of the apparatus the better. A more minute reference to the construction of these scum pipes was made in the monthly abstract of October last; and now that these three classes have been in operation for some time, it is thought that the results of their working may shortly be made a matter of comparison, which, as soon as opportunity offers, will be communicated to the members.

"The use of soda, for the prevention of incrustation, is found of considerable advantage, and increasingly adopted. It is, however, better introduced in small regular doses, than in large infrequent charges. In many cases there might be fitted to the suction pipe of the feed pump a funnel mouth by means of which the requisite charge could be introduced to the boiler without difficulty; its rate of ingress being regulated by a tap between it and the suction pipe. In some cases a separate feed pump has been adopted, fitted with a small cistern containing a day's supply, and this arrangement has been found to work most satisfactorily.

"In conclusion, there are but few cases of incrustation which the use of soda, combined with regular blowing-out from the surface of the water, will not check.

CONSTRUCTION OF BOILERS.

"The consideration of the previous defects, to which the boilers under inspection have been found to be liable, will, it is trusted, prove of assistance to members wishing to lay down new boilers, as well as to those whose business it is to construct them.

"But it is thought, however, that a further service yet might be rendered. Such ample opportunity has been enjoyed of seeing when in work, as well as of examining while at rest, considerable numbers and varieties of boilers, and such full information has

been collected with regard to them by the association, that it is thought if the best proportions were collated, and put together in the form somewhat of a specification, it would prove of more assistance still than observations and analyses of defects alone ; not by any means a minute and technical specification, but a systematic explanation of such proportions as have been found to exist in those boilers, giving the best results, and needing the least repair. It was intended to include this in the present report, but, finding that it could not be given complete, it is reserved for insertion in the printed monthly reports which circulate amongst the members.

EXPLOSIONS.

" It is to be regretted, that no means exist of ascertaining the whole number of steam boiler explosions that occur throughout the United Kingdom, and there can be no doubt that many are never recorded at all. There are known, however, to have occurred during the last year, no less than 30 explosions, from which, at least, 87 persons have been killed, and 89 injured. Of the number of lives lost by some of the above, no account could be obtained ; while, from one of them, as many as 29 persons were killed, and 12 injured ; from a second, 12 were killed, and 24 injured ; and from a third, 6 were killed, and 8 injured.

" The following list gives the description of boiler to which the explosions have occurred, with the number of each class, as well as of the persons killed and injured :—

Four haystack boilers—12 persons killed, 5 others injured.

Six plain cylindrical egg-ended boilers—6 persons killed, 6 others injured.

Three iron-works' boilers—47 persons killed, 44 others injured.

Three plain single-flued Cornish boilers—2 persons killed, 3 others injured.

Two plain double-flued Lancashire boilers—4 persons killed.

Three locomotive boilers, of tubular construction—4 persons killed, 5 others injured.

One agricultural boiler, of tubular portable construction—4 persons killed, 4 others injured.

One kitchen-range boiler—1 person killed.

Also seven other boilers, of the construction of which no reliable information could be obtained, and from the explosion of which, 7 persons were killed, and 22 others injured.

"The haystack boilers, referred to above, were externally fired, and exploded through the failure of the part exposed to the action of the fire.

"The plain egg-ended boilers, fired underneath, were found, in all cases, to have exploded from the rending of the transverse seams of rivets. One of these boilers exploded at the bottom of a coal mine, and in another case three boilers working side by side exploded simultaneously. Details of all these have already been reported in the monthly abstracts for February, March, and August, respectively, so that further particulars need not now be given.

"The iron-works' boilers were all heated by the flames passing off from the iron furnaces, which played not only upon the external shells of the boilers, but also through their internal flues.

"The first of these was what is termed an 'upright furnace' boiler, in which the flames, passing off from sometimes as many as four iron furnaces, impinge upon the exterior, and then pass into an interior descending flue. In this case the crown of the descending flue collapsed from original defective construction.

"The second explosion occurred to a precisely similar boiler, but in this case the external shell gave way at the seams upon which the flames from the iron furnaces impinged.

"The third boiler was a plain single-flued 'Cornish' one, fired externally by the flames passing off from two iron furnaces, and internally by those passing off, through its flue tube, from another. The explosion was caused by collapse of the internal flue-tube, arising from defective construction, and might have been prevented had the flue been strengthened, either with flanged seams, or hoops of angle iron, T iron, or other suitable form.

"Each of the three iron-works' boilers was personally examined subsequently to its explosion, and full particulars were given in the March, April, and December monthly abstracts.

"Of the three explosions which occurred to plain 'Cornish' boilers, *one was caused by collapse of the flue-tube, consequent*

upon shortness of water. This appears to have been caused by carelessness, the gauge-glass having been broken. The shell of the boiler was uninjured, and the only damage done was by the percussive action of the steam and water, in a direct line with the furnace tube.

"Of the other two no reliable information could be obtained; they are reported, however, to have failed at the front end-plate.

"Both the explosions, which occurred to boilers of the plain double-flued 'Lancashire' class, were caused by external corrosion of the plates, which were so eaten away in one case as to be reduced in thickness to the sixteenth of an inch, and in the other to that of a sheet of paper.

"One of these boilers was under the inspection of this association, but the opportunity had not been afforded to its inspectors of making the regular annual 'thorough' examinations, the importance of which has been so repeatedly called attention to in the reports. This subject was gone so fully into in the monthly report for July last, shortly after the explosion happened, that it is needless to repeat the details here; while the particulars of the other, which also was personally examined, will be found in the monthly report for last December.

"The locomotive boilers, in every case, exploded from thinning of the plates, caused by internal corrosion, it being a general practice in the management of locomotives only to make a thorough internal examination of the shells of the boilers, when the flue-tubes are renewed. This, in some cases, has allowed an interval of as much as seven years to elapse between one examination and another, during which time the boiler has been working in a state of complete uncertainty, the actual condition of the plates being unknown. The use of the hydraulic pressure is objected to by several locomotive engineers, though not by all; it is a point which has provoked a good deal of discussion, and is too lengthy to enter upon on the present occasion. It may, however, be stated, in brief, that no case has been met with, in the experience of the association, in which injury has resulted from the judicious application of this test, and also that no opportunity will be lost of contributing any information on the subject that the experience of the association may afford. It is one of considerable interest, and affects the safety of the whole travelling public

"The kitchen-range boiler exploded from accumulated pressure, the taps of both the inlet and outlet pipes being closed at the same time, in consequence of which there was no escape for the steam, there being no safety-valve.

"Of the cause of the explosion of the agricultural portable boiler, as well as of those which occurred to the remaining seven at the bottom of the list, no reliable information has been received, while the distance at which nearly all of them happened precluded personal examination.

"The causes of the above explosions may be systematized as follows:—

"Of 30 explosions, which happened during the year 1862, 11 occurred to externally fired boilers from failure of the plates exposed to the action of the fire; 3 resulted from internal corrosion, and 3 from external; in addition to which, 4 were due to improper original construction, one to shortness of water, and another to accumulated pressure through want of a safety-valve; while 7 occurred at a distance which precluded a personal investigation of their causes, at the same time that no reliable information could be obtained with regard to them.

"It may be added that the explosion which occurred to a double-flued 'Lancashire' boiler, and from which one life was lost, is the third fatal explosion which has happened to any of the boilers under the inspection of this association, since its establishment eight years ago; to which should be added three cases of collapse of furnace flues, not attended with any serious consequences, and which arose, in two instances, if not in all three, from shortness of water. During this period 712 dangerous defects have been pointed out in the boilers under inspection, from which serious injury might have arisen in each case; while, upon limited inquiry only, it has been found that no less than 213 explosions have occurred in that time to boilers not under the inspection of this association, which have been attended with the loss of 472 lives, in addition to serious injury to 512 persons, and considerable damage to property.

ENGINES.

"The depressed state of trade during the past year has so disorganised the *ordinary working* of most of the mills, that it has

been found impossible to draw up a reliable comparative table of the economic duty of the engines. Indicator diagrams alone, however, from most of the engines under inspection, never afford the necessary data for correct comparison, since so much steam is drawn off for purposes other than that of motive power. It becomes, therefore, highly desirable that water metres should be fixed to each series of boilers, so as to ascertain the amount of water evaporated. This would enable a comparison to be made of the evaporative power of different boilers, and of the value of different coals, while at the same time the diagrams would afford an indication of the working of the engines.

"Two pair of engines, built during the past year, have had their cylinders fitted with steam jackets; and a superheating apparatus, for raising the temperature of the steam in its passage between the boiler and engine, has been introduced in two or three instances. The object of both these arrangements is economy of fuel, and it is intended, as soon as possible, to investigate the results obtained, in order to communicate them to the members.

"A 'surface-condenser' is being constructed for a pair of beam-engines, and will, it is expected, be put to work early this year. 'Surface condensation' is the most radical preventative of incrustation, since, whatever the character of the condensing steam may be, this condenser returns to the boiler distilled water; the same quantity, with the exception of a small amount of waste, being used again and again. There are many cases in this district where this will prove valuable; and the results of the application, in the present instance, will be a matter of considerable interest to many of the steam-users of the district.

CONCLUSION.

"A very brief recapitulation may be allowed, in conclusion, of some of the points attained during the past year.

"'Surface blowing-out' has made considerable progress. 'Steam-jackets,' so long discarded in this district, have been revived, and 'superheating' introduced, while a 'surface-condenser' is about to be applied.

"Although these arrangements are not in general use here, *they have been fully tested elsewhere, and it is thought that*

much may be gained by importing, as it were, into this district the engineering experience of others. For instance, the 'steam-jacket' has, in combination with the use of highly-expanded steam, been the principal element in the attainment of that economy for which the Cornish engine has for so long since been notorious, while 'surface blowing-out' and 'surface-condensation,' as well as 'superheating,' are due to marine engineering practice, which has developed a higher economic result than that generally obtained in this district.

"Although it is true that all really sound and beneficial mechanical arrangements, practised in one district, will, in time, surely find their way into and secure for themselves adoption in others; yet it is thought that this association can do much to hasten this process—too frequently a tardy one—by circulating, upon these points, information amongst its members; and to assist in doing which, as far as it lies in my power, will always be regarded by me, not only as a duty but a source of satisfaction and pleasure.

"It is trusted that, during the present year, the mechanical arrangements just referred to will be fully tested, and a general confidence and adoption secured in this district, for such of them as prove worthy of it; so that the desire expressed at the conclusion of the last annual report may be realized, namely—'That no year may be allowed to pass without a decided mark of progress being clearly stamped upon the engineering practice of the district, by this association.' For the accomplishment of this, however, the co-operation of the members is absolutely necessary. Comparative returns of the working of engines cannot be made, unless the members have their engines indicated; neither can the consumption be calculated, without accurate returns; nor the evaporative power of the boilers arrived at without the application of water meters."

"Another meeting of the executive committee of this association took place at their offices, 41 Corporation Street, Manchester, on March 31st, 1863, William Fairbairn, Esq., in the chair.

"During the past month there have been examined 370 engines—1 specially; 492 boilers—6 specially, 17 internally, 60 thoroughly, and 409 externally, in which the following defects have been found:—Fracture, 2 (1 dangerous); corrosion, 18 (2

dangerous); safety valves out of order, 4; water gauges ditto, 24 (1 dangerous); pressure gauges ditto, 16; feed apparatus ditto, 5; blow-off cocks ditto, 47 (1 dangerous); fusible plugs ditto, 5; furnaces out of shape, 3 (1 dangerous); over-pressure, 2; deficiency of water, 2; blistered plates, 2. Total, 130 (6 dangerous). Boilers without glass water gauges, 1; without pressure gauges, 1; without blow-off cocks, 36; without back pressure valves, 58.

EXPLOSIONS.

"It will be remembered that in last month's report no detailed particulars were given of No. 1 explosion, which occurred to a boiler not under the inspection of this association, and which was of the double furnace internally fired class. Particulars have, however, been since obtained, and show that the explosion was of a very simple character. It was the practice to keep up a fire in this boiler throughout the night for the purpose of heating the mill, and a boy was left in charge to attend to it. The demand made upon the boiler for steam was such that no supply of water would carry it through the night, and therefore it was the duty of the attendant to make up the deficiency with the donkey-pump. This, however, he neglected to do, in consequence of which the furnace crowns were laid bare, the plates became red-hot, and collapse ensued. The boy was absent from the boiler at the time of the explosion, neither was any one else near it, and thus happily no lives were lost nor any one injured, while the damage to property was confined to that done to the boiler itself.

"This is just one of those cases in which a low-water safety-valve would have been of service, not only by its giving an alarm before the furnace crowns were laid bare, but also by letting off the pressure of the steam.

"Two explosions have occurred during the past month to boilers not under the inspection of this association, by which 15 persons were killed and 16 others injured, making a total of 31. Both boilers have been personally examined subsequent to the explosion. The following is the monthly tabular statement:

TABULAR STATEMENT OF EXPLOSIONS,
FROM FEBRUARY 21ST, 1863, TO MARCH 27TH, 1863, INCLUSIVE.

Index No.	Date.	General Description of Boiler.	Persons Killed.	Persons Injured.	Total.
No. 4	Feb. 23	Vertical Ironworks Boiler, internally fired,	13	15	28
No. 5	Mar. 17	Ordinary double flue or 'Lancashire,' internally fired,	2	1	3

"No. 4 explosion occurred at an ironwork to a boiler connected to a series of eighteen others. It was very similar in general construction, though not precisely so, to those known as upright furnace boilers, like which it stood erect, was of considerable height, and surrounded with brickwork. They, however, are heated by the flames passing off from the iron furnaces, which play first upon the outside of the shell, then pass through openings in the side into an internal descending flue, and escape to the chimney; while the boiler in question had its own independent furnace placed in the internal flue, which was thus converted from a descending to an ascending one, the openings at the side becoming outlets for the flame instead of inlets. The top of the boiler was hemispherical, and the bottom flat; whereas in the ordinary furnace class, both ends are hemispherical, which is an important difference.

"The boiler was 20 feet high, and about 9 feet 6 in. diameter. The internal fire-box was 10 feet high, 4 feet 6 in. diameter at the crown, and also for about the first 3 feet 6 in. below; from which point it tapered outwards to a diameter, at the bottom, of 6 feet 6 in., leaving an annular water space all round, about 18 inches in width between it and the shell. This fire-box was united to the shell at the bottom by a flat plate connected by rings of angle iron inside the water space. The crown of this internal fire-box was slightly domed, and flanged at its attachment to the cylindrical sides, being amply stiffened by six angle irons laid across and well riveted to it. At the upper part of the fire-box were the two outlets previously referred to, and which were formed by short transverse flues passing through the water space, and thus establishing a communication between the internal furnace and the external flue. These short flues, which

were opposite one to the other, and at right angles to the furnace door, were 2 feet 6 in. in diameter, and attached by rings of angle iron at each end.

"The thickness of the plates was: in the hemispherical end and cylindrical sides of the external shell, $\frac{3}{8}$ in.: in the flat plate at the bottom of the water space, 7-16th in.: while all the angle irons were 3 in. by 3 in. and $\frac{1}{2}$ in. thick. In the fire-box the thickness of the crown plate was $\frac{1}{2}$ in., and that of the sides 7-16th in.

"With regard to the lay of the plates, that in the shell was according to the usual plan, being radial in the hemispherical end, and circumferential in the cylindrical sides, the seams in the latter breaking joint; while in the taper portion of the fire-box the plates were laid longitudinally, and thus, which it is important to notice, the seams were in line for a length of between 6 feet and 7 feet. The riveting was single throughout, and the seams were the ordinary overlap.

"The boiler had been fitted with a float, two gauge taps, one feed stop valve, one feed back-pressure valve, and one lever safety valve of 5 in. diameter, which was loaded to a pressure of nearly 50 lb., and at all events would have allowed the steam to have reached that pressure when blowing off freely. Also there were two junction valves, one of which was in the steam pipe communicating with the entire series of boilers, and the other in that connected to the steam hammer. There was no steam pressure gauge on the boiler itself, but one was fixed to the main steam pipe beyond the junction valve, and thus afforded no indication of the pressure of the steam within the boiler when it was shut off from the others in the series. Both of the junction valves were closed at the time of the explosion, and thus the safety valve formed the only outlet for the steam. What the pressure then rose to cannot now be ascertained, the steam pressure gauge, as just pointed out, giving no indication under such circumstances. The safety-valve, however, was found to be free after the explosion, and there is no reason to conclude that it had been otherwise previously. But it is apparent from this how circumstances will arise which make it important that every boiler *should* be fitted with a duplicate safety-valve, as well as with its *independent* pressure gauge.

"A very general impression exists that the cause of most, if not of all, the explosions that occur at ironworks, is to be found in the old age and dilapidated condition of the boilers: such, however, was not the case in this instance: the workmanship of the boiler was satisfactory throughout, and its condition good. It was reported to have been at work only a few months, which its appearance corroborated. Were all boilers in as good a condition as this one was, explosions would be of much rarer occurrence than at present.

"The cause of this explosion was clearly not 'shortness of water;' the crown of the fire-box was uninjured, the colour of the plate black, a thin scale covering portions of it, while the rents made in the boiler were not those which a deficiency of water would have occasioned.

"A serious oversight had been made in the design of the boiler, the top end being hemispherical and the bottom flat. The hemispherical end would, when the steam was fully up and blowing off freely, have an upward pressure of nearly 250 tons acting upon it and tending to tear it away from the bottom. There would be an equal downward strain counteracting this, induced by the pressure of the steam upon the crown and tapering sides of the fire-box, combined with that upon the flat plate forming the bottom of the annular water space. As long as the attachment between the bottom and the top of the boiler held good, the two forces would be in equilibrio, and the boiler remain at rest upon its bed. But should the attachment fail, the upward force would instantly shoot the top of the boiler up into the air with a buoyancy of 250 tons, which, it may be remarked, is equal to the weight of a long railway train, including the engine and tender fully equipped with coke and water. This action is exactly what took place. The flat plate at the bottom gave way, rending completely round through the seam of rivets, at the outside ring of angle iron which attached it to the shell; when the boiler flew up and was carried to a distance of 160 yards from its original seat. The brickwork at the top of the chimney was shaken, and there were marks of violence on the crown of the boiler, so that it is possible that it struck the top of the chimney in its course. There is nothing surprising in this when the amount of the pent-up force of steam within so large a boiler

is considered, and the due appreciation of which shows how unnecessary is the supposition of the existence of explosive gaseous compounds, or any force greater than that of the steam itself; while the propagation of such theories only tends to divert attention from the real cause of steam boiler explosions. The rent at the flat bottom plate, however, was by no means the only one that was made. The short transverse flues passing through the water space, and which considerably assisted the bottom plate, also gave way and were torn from both the shell and fire-box, their mode of fracture giving unmistakable evidence of the upward flight of the shell. The resistance of these flues to fracture had severed the fire-box in the waist at the ring seam of rivets, at which the longitudinal plating terminated: and thus the fire-box crown, as well as one ring of plates with the two short flue tubes, had flown up together with the shell, which made a somewhat remarkable and complicated feature in the development of the rents. Added to this the remaining portion of the fire-box, which was taper, and plated longitudinally, rent at one of the longitudinal seams opposite the fire-door, and collapsed at that part.

"Some difference of opinion has existed among the engineers who have examined the boiler, as to whether the explosion originated at the rent of the flat bottom plate, or at the collapse of the fire-box. Though there may be some difficulty in determining which was the weaker spot of the two, there has been none in deciding that the boiler was inherently defective; and the opinion has been unanimous that there is no evidence for attributing the explosion either to 'shortness of water' or to excessive pressure, but that it was clearly owing to the mal-construction of the boiler itself. It may be added that the application of the hydraulic test would have detected and exposed the weakness both of the fire-box and bottom flat plate, the former by its temporary flattening, the latter by the moving and rising of the outer shell.

"The jury at the coroner's inquest came to the following conclusions, which are quite in accordance with the preceding report:—'That the explosion was caused by the bad construction of the boiler. That every boiler ought to be supplied with a *steam pressure gauge*, and that no new boiler ought to be put to

work before it has been examined by some competent engineer and pronounced to be safe.'

"No. 5 explosion occurred to one of two mill boilers working side by side and connected together, both being of the plain double flued internally fired class, termed 'Lancashire.'

"The length of the one in question was 28ft., the diameter of the shell 10ft., and that of the flues, which were parallel throughout their whole length, 3ft. 9in.; the thickness of the plates were seven-sixteenths in the shell, and three-eighths in the flues. The boiler had been fitted with one glass water gauge, one feed back-pressure and stop valve combined, one blow out tap, one lever safety valve, and one Schaeffer steam pressure gauge, common to both boilers. The pressure at which the safety valve was stated by the engine attendant to have blown off, was 30lb. on the square inch, which an examination of its dimensions, lever, and weights corroborated.

"On examining the boiler it was found that the right-hand flue had collapsed from one end to the other, and by the flattening action had become severed completely in two at some of the ring seams of rivets, as well as torn away from the end plate at the back of the boiler. The boiler had not stirred from its original position, and the connections to the one alongside remained unbroken.

"The rush of water, however, from the opening at the back had blown up the brick flue and carried away the end wall of the boiler house, in consequence of which a floor above, as well as some cast iron girders by which it had been supported, were brought down. It was by the fall of the building that the three men received their injuries, one of whom was found to be dead when dug out of the *debris*. At the front end of the boiler the furnace mountings had been blown off.

"The amount of damage done to the surrounding property was comparatively inconsiderable, and this is generally found to be the case where explosion is confined to collapse of the internal flues. Where, however, the external shell gives way, the consequences are much more serious. The boiler does not then remain quietly in its seat as it did in the present instance, but—to the effect of the percussive action of the steam, which was the only element of injury in this case—adds that of the flight of

the fragments of the shell, as in the preceding No. 4 explosion, as well as in the one that occurred to an ironworks boiler in December last, the particulars of which were given in the report for that month.

"With regard to the cause of the collapse, there was no evidence of 'shortness of water,' judging from the appearance of the plates: added to which, the other furnace in same boiler remained unaltered in shape, which could not have been the case had deficiency of water occurred: while, in addition, it appeared that the collapse of the flue had commenced at the middle of its length, and not over the furnace, where the shape was less distorted than at any other part.

"The collapse cannot be fairly attributed to 'shortness of water,' but its true cause will be found in the construction of the flue, which was not strengthened with flanged seams or the addition of any hoops. Such a flue as the present, of so large a diameter as 3ft. 9in., and 28ft. long, made of plate only three-eighths thick, is not safe for regular work with steam at a pressure of 30 lb. per square inch, as was the case in this instance. It might work for a time, but still there would be a risk, as the event proves; a risk that might have been avoided had the flue been strengthened with any of the approved methods, namely, flanged seams, or hoops, either of angle iron, T iron, bridge rail section, or any other suitable form; to the importance of adopting which attention has been called, it is feared with tedious frequency, though an apology for so doing it is thought may be found in the repeated occurrence of such explosions as the present, and in the loss of life consequent upon them.

"It may here be added, there is every reason to conclude that the boiler in question was an illustration of the danger referred to in previous reports, arising from internal flues being actually oval, although supposed to be circular. The angle iron rings at the end plates were circular, but the inclination of the axis of the collapse of the flue indicated that the middle portion had been oval. The other flue alongside was evidently so, and had in consequence been strengthened by two stays attached to the crown. The flues of all the boilers under the inspection of the association are gauged to ascertain their actual shape, when the *members allow an opportunity of making 'thorough examina-*

tions,' without which it cannot be done; and very numerous are the instances in which flues, previously supposed to be circular, are found on actual measurement to be oval.

"This explosion is one that must be added to the category of those caused by mal-construction of the boiler, and cannot be termed accidental. The application of the hydraulic test would have detected the weakness, and the adoption of any of the approved methods of strengthening flues mentioned above prevented the explosion. These preventives have now become common knowledge, they can be applied at little expense and by any ordinarily competent boiler maker, and thus are within the reach of all. It may therefore be fairly pointed out that their rejection by one manufacturer is an act of injustice to others, since nothing can operate more directly to induce Government interference with the present unfettered use of steam than the frequent occurrence of loss of life, through the neglect of precautions so simple as those just alluded to."

At the last ordinary monthly meeting of the Executive Committee of this Association, held at the offices, 41 Corporation-street, Manchester, on Tuesday, May 26th, 1863, Mr. L. E. Fletcher, chief engineer, presented his Monthly Report, of which the following is an abstract:—

"During the past month, there have been examined 257 engines—1 specially; 420 boilers—10 specially, 11 internally, 77 thoroughly, and 322 externally, in addition to which one of these boilers has been tested by hydraulic pressure. The following defects have been found in the boilers examined:—Fracture, 8, (3 dangerous); corrosion, 22; safety-valves out of order, 1; water gauges ditto, 11; pressure gauges ditto, 6; feed apparatus ditto, 2; blow-out apparatus ditto, 3; fusible plugs ditto, 1; furnaces out of shape, 2 (1 dangerous); over pressure, 2 (both dangerous); blistered plates, 2 (1 dangerous); total, 60 (7 dangerous). Boilers without glass water gauges, 2; without pressure gauges, 5; without blow-out apparatus, 17; without back pressure valves, 34.

"The occurrence of explosions during the past few months has been so frequent, that the reports of their details have prevented any notice of the defects found to exist in the boilers under inspection, further than that given in the monthly lists as

above; and, therefore, the present opportunity may be taken for some slight amplification.

"Serious cases of corrosion continue to be met with at the bottom of those boilers which are set upon brick mid-feathers, running underneath them from one end to the other along the centre or keel line. In this mode of setting, any water which may fall upon the boiler, or leak from the seams, trickles down the shell, and settles on the top of the mid-feather, in contact with the plates. Also where damp exists in the flues, it easily rises through the mid-feather and reaches the boiler. Corrosion may be going on along the centre of the mid-feather and not be visible at the sides, and thus pass undetected even on careful examination—several instances of which have recently been met with.

"In one case, a boiler, 10 ft. 5 in. in diameter, and of plates 7-16ths thick, was found, upon the removal of the brickwork, to be deeply channelled for a width of 6 in. along the bottom at the centre of the seating, no indication of which was given at the sides of the wall, nor was it detected by hammering internally, but remained unknown until the removal of the brickwork. In another boiler, the shell of which was 8 ft. 2 in. diameter, and $\frac{3}{8}$ in. thickness, the plates were found to be channelled longitudinally along the centre of the mid-feather for a width of 8 in. The seating was 15 in. wide, and the channel died out at 3 in. from the outside, thus giving no external sign. In a third boiler, the flues of which were damp, the whole of the plates in contact with the mid-feather were found to be corroded and as much as a quarter of an inch in thickness eaten away. Other instances might be adduced, but the character of the injury is so similar in each case that it would be tedious. Those already given will show the grounds upon which the following recommendations are made:—

"1. Wherever it is practicable to do so, dispense with mid-feathers altogether, and substitute what are termed two side walls for them. 2. In those cases where the small size of the boiler forbids this, make the bearing surface of the mid-feather wall as narrow as possible. 3. Any that must be retained in use, should, in preparation for annual 'thorough' inspection, be removed—at least where in contact with the transverse seams of rivets—in order to admit of complete examination.

"Further cases of corrosion may be mentioned occurring to other boilers than those set upon mid-feathers.

"A tubular boiler, without any external flues, was found so deeply channelled at the bottom of the shell at the transverse seams of rivets, that the plates were reduced to the thickness of a sheet of paper, and a hole knocked through them in sounding their strength with a hammer. A second boiler, of ordinary double furnace, internally fired construction, was so eaten away by corrosion at the first bottom plate from the front, that, as in the preceding case, a hole was made on examination; the corrosion being due to leakage from the glass water gauges, and mud-hole joint, as well as to the practice of slacking the ashes while lying at the front of the boiler. In another case, where the cross wall below the front end of the boiler was as much as two feet in thickness, the plates were corroded nearly through. So great a thickness as 2 ft. for these walls is quite unnecessary, as well as objectionable, and it is recommended that they should be removed periodically for the examination of the plates.

"Several cases have been met with during the past month of injury occurring to externally-fired boilers at the parts immediately over the furnace, the plates bulging, cracking at the rivet holes, and the seams straining and leaking. One of our members has contributed a sample plate cut out from a boiler of this class, which is bulged down at the solid, and cracked completely through, although the boiler was amply supplied with water; this plate is a fair sample of the danger of the externally-fired class, and lies at the office for the inspection of members.

"A safety-valve, the spindle of which passed through a bushed hole in the cover, was found to fit so tight as to be quite fast. This bush had been fitted to prevent the inconvenience arising from the escape of steam, under the impression that a safety valve was unnecessary, as long as the boiler was provided with a steam pressure gauge.

"*Explosions.*—A report relative to Explosion No. 9, recorded in the last month's abstract, has since been received from an engineer who examined the boiler shortly after the explosion had occurred, and from which it appears that the boiler, which was of plain cylindrical egg-ended construction, and externally-fired, had *rent*—as is so constantly found to be the case in this class

—at the transverse seams over the fire, the shell dividing into two parts, which were thrown some distance asunder. One boiler only, and which was not under the inspection of this association, has been reported to have exploded during the last month; the explosion occurring at too great a distance from Manchester to admit of a personal investigation. Should any particulars of interest be ascertained, they will be communicated in the next monthly report.—The explosion will rank as No. 10 in this year's list."

At the last ordinary monthly meeting of the Executive Committee of this Association, held at the offices, 41 Corporation-street, Manchester, on Tuesday, June 30th, 1863, Mr. L. E. Fletcher, chief engineer, presented his Monthly Report, of which the following is an abstract:—

"During the past month there have been examined 340 engines—2 specially; 528 boilers—10 specially, 12 internally, 104 thoroughly, and 402 externally, in which the following defects have been found:—Fracture, 8 (2 dangerous); corrosion, 34 (3 dangerous); safety-valves out of order, 9; water gauges ditto, 21; pressure gauges ditto, 9; feed apparatus ditto, 2; blow-out apparatus ditto 35; fusible plugs ditto, 13; furnaces out of shape, 4 (2 dangerous); over pressure, 2 (both dangerous); blistered plates, 3; total, 140 (9 dangerous); boilers without water gauges, 8; without pressure-gauges, 8; without blow-out apparatus, 13; without back pressure valves, 39.

EXPLOSIONS.

"No. 10 Explosion—The fact of this explosion having occurred was stated in last month's report, but no detailed particulars had then been received. It has since been ascertained that the boiler was a plain cylindrical egg-ended one, externally fired, and that the explosion was caused by rents commencing at the seams over the furnace, which has so frequently been found to be the case in this class of boiler, and called attention to in these reports. Two other explosions of a very similar character have happened during this month, particulars of which are given.

"Nine explosions have occurred during the last month, by which eleven persons have been killed, and twenty-one others *injured*. One of these explosions, which resulted from collapse

of the flue, and by which no injury was done either to persons or surrounding property, occurred to a boiler under the inspection of this association; while in the eight remaining cases not one of the boilers was under its care. Details will be found below. The following is the monthly tabular statement;—

TABULAR STATEMENT OF EXPLOSIONS

FROM MAY 23D, 1863, TO JUNE 26TH, 1863, INCLUSIVE.

Progressive No. for 1863.	Date.	General Description of Boiler.	Persons killed.	Persons injured.	Total.
No. 11	May 29	Locomotive,	1	1	2
No. 12	May 30	Cylindrical egg-ended, externally fired,	5	12	17
No. 13	June 2	Upright furnace, internally fired,	0	0	0
No. 14	June 13	Details not yet ascertained,	1	5	6
No. 15	June 13	{ Ordinary single flue, or 'Cornish' internally fired, }	0	0	0
No. 16	June 14	Cylindrical egg-ended, externally fired,	1	0	1
No. 17	June 15	Details not yet ascertained,	2	3	5
No. 18	June 15	Marine,	1	...	1
No. 19	June 26	Details not yet ascertained,	0	0	0
Total,			11	21	32

"No. 11 explosion occurred to the boiler of a locomotive engine while running with a passenger train. Between fifty and sixty persons were injured and four killed. This result was not occasioned however by the explosion only, but principally by the train running off the line. Whether the engine leaving the rails was the cause or the effect of the explosion is an interesting question, and one now undergoing strict investigation. All the facts likely to prove of value to steam users generally, which may be elicited with regard to this explosion, will be given to the members of the association at the earliest opportunity after the close of the inquiry. The only injuries directly attributable to the explosion are those which happened to the engine-driver and fireman, both of whom were severely scalded, the latter having died in consequence.

"No. 12 explosion, from which five persons were killed and twelve others injured, took place at an ironworks. The boiler in question, which was not under the care of this association, was *personally examined shortly after the explosion happened,*

and found to be of cylindrical egg-ended construction, having an internal flue of horse-shoe shape, both the inlet and outlet of which passed through the further end of the boiler, the remainder of the flue being quite independent of the shell, and thus not forming any longitudinal tie from front to back. The boiler was externally fired, the flame first passing underneath the shell, and then entering the flue at one leg of the horse-shoe, and escaping to the chimney through the other. The length of the shell was 28 feet, the diameter 8 feet 6 in., and the thickness of the plates seven-sixteenths, while the blowing-off was about 40 lbs.

"The boiler had rent completely into two parts at the fourth transverse seam from the front end, the larger portion of the shell flying forwards in a straight line from its seat, turning a summersault in its course, and landing in a position quite the reverse of its original one; the egg-end pointing to the brickwork seating and the open one from it. The smaller portion had flown to a much greater distance than the other, and not, as is usually the case, in a direction immediately opposite, but at right angles to it. A sister boiler working alongside, and connected to the one in question, was moved laterally, sufficiently so to disturb the brickwork seating and break the steam pipes, though not to unseat it altogether.

"With regard to the cause of the explosion. The boiler was fifteen years old, the plates over the furnace had already been repaired, and it was stated that the seams at that part had been observed to be leaking only a quarter of an hour before the explosion took place; while, in addition, the shell was found to be patched in several places, and the plates cracked from the rivet holes to the edge. It is concluded therefore, on consideration of all the circumstances, that the boiler could not have been in good condition, the correctness of which it is thought derives some corroboration from the fact, that the boiler alongside was found at the time of making this examination to be also leaking at the seams over the furnace, and that considerably, although not under pressure. An examination of the fractures, as well as a consideration of the direction in which the parts had flown, led to the conclusion that the rent had commenced at a longitudinal seam of rivets, extending for some two or three plates over

the furnace. The rent ran along as far as this longitudinal seam extended, and when met by a plate crossing it or 'breaking joint,' as it is termed, then developed into a transverse rent, and completely severed the shell in two. It is thought that the fact of this longitudinal rent in the furnace end of the shell, being situated on one side of the centre or 'keel line,' accounts for that portion having been blown laterally, and that the upward direction which it had evidently taken had caused the summer-sault of the remaining and larger portion. The explosion, therefore, is attributed to the imperfect condition of the boiler; and although such defects would not be dangerous in a suitably-constructed, double-flued, or 'Lancashire' boiler, which is always internally fired, they are generally found to be fatal in those boilers which are fired externally; while in the present case the effect was aggravated by the fact of the seams of rivets over the fire being in line, and the diameter of the shell being as much as 8 feet 6 in.

"No. 13 explosion, by which no one was injured, or the surrounding property damaged, occurred to a boiler under the inspection of this association, the particulars of which are as follow:—

"The boiler was an upright furnace one, working in connection with two others of similar construction to itself. It was heated by the flames passing off from a furnace employed in preparing heavy forgings; the flames passing through an internal tube in the centre of the boiler, which ran directly from the top to the bottom. The extreme height of this internal flue was 26 feet 2 in., but it was not of one diameter throughout. In order to admit of a brickwork lining, to guard the flue above water line the upper part was made of a larger diameter than the remainder, and attached to it by a flanged plate which formed a 'set-off' or shelf, on which the brickwork rested; again, the lower portion of the tube had a bell-mouth at the bottom, to afford an easy entrance for the flame. The length of the upper part was 11 feet 4 in., and the diameter 3 ft. 3 in.; the length of the intermediate portion was 10 feet 4 in., and the diameter 2 feet 6 in.; while the length of the bell-mouth, was 4 feet 6 in., and the diameter, at the base, 3 feet, the thickness of the plates being three-eighths of an inch throughout, and the blowing-off pressure 55 lbs.

"The explosion, which did not in any way disturb the original position of the boiler, resulted from collapse of the internal flue tube, the collapse being confined to the intermediate portion just described, which it rent at about the middle of its length.

"A tube of such small dimensions as those just given, namely, only 10 feet 6 in. in length, and 2 feet 6 in. in diameter, made of plate three-eighths in thickness, if of good material and workmanship as this one was, would be amply sufficient for a pressure of 55 lbs. if working under ordinary circumstances. It has been since ascertained that this flue has been reconstructed of plates of precisely the same thickness as the old one, and that, on submitting it to the hydraulic test, it was found to sustain a pressure of 120 lbs. per square inch without yielding in the slightest degree, although carefully gauged. This clearly shows that the flue did not collapse from the weakness of its original construction. This would suggest the conclusion that the water supply had been allowed to run short, but no positive indications of the plates having been overheated appeared upon examination, though this may, however, have taken place on previous occasions without its being known. On account of the height of these upright furnace boilers, the glass gauges become inaccessible, and the one in question was fitted with two gauge taps only, carried down by means of syphon pipes to within reach from the floor. Thus the water could sink below the proper level without affording any external indication, and would consequently pass unknown should the gauge taps be neglected. This may have happened without any immediate collapse of the tube taking place, although the flue would be materially weakened by it, and rendered liable to give way some time after in consequence. It is impossible to say whether the flue tube was getting out of shape or not, since the boiler had been in such constant work that no opportunity was afforded the association of making an 'internal' and 'thorough' examination for upwards of three years. This may not therefore be an improper time for calling attention to the importance, generally, of having spare boilers, so that a suitable opportunity may be afforded for examination, as well as for cleaning and repair. The boiler was found to be heavily incrustated with hard scale, which must considerably have tended to the overheating and weakening of the flue, to which these vertical boilers are

always prone, from the tendency of the ascending steam to cling around the tube and prevent the contact of the water. The inaccessibility of the gauges and fittings of these vertical boilers, on account of their height, is another disadvantage connected with them, and indeed a thoroughly good and safe furnace boiler must still be considered as a desideratum.

"No. 16 explosion happened at an ironworks, to an externally-fired boiler, 40 feet long, 8 feet in diameter, made of plates seven-sixteenths of an inch thick. The shell of the boiler gave way immediately over the furnace, the fireman being scalded to death from the stream of hot water issuing from the rent. The boiler had been repaired at this part, by putting on a new plate, two months previous to the explosion; and it was at this plate that the rent occurred.

"This boiler, which was not under the charge of this association, was not personally examined on the occurrence of the explosion, but an engineer who inspected it shortly after has kindly furnished the following particulars:—The plate ripped open through the solid metal in two places, the rent being about 15 in. long and 1 in. wide; while the parts surrounding it were a good deal cracked, and the seams patched, so that the bottom of the boiler was evidently in a very defective state. The ruptured plate was about seven-sixteenths of an inch thick, and did not appear of very good quality, as if not thoroughly welded in rolling; but the fractures were not, properly speaking, 'blisters,' since the whole thickness of the plate had come down at once. In addition to the inferior character of the plate, the boiler was heavily coated with incrustation, and this had accumulated at the bottom for a depth of 3 inches just over the fracture, and extended for a space of 4 ft. by 2 ft. This mud had hardened so much that the water and steam ploughed but a small hole through it in rushing out. There can be little question that this coating of mud had kept the water away from the plate, and thus led to its becoming overheated, from which it gave way. There was plenty of water in the boiler at the time of the rupture.

"It will be clear that it is scarcely possible for such a cake of sediment to have formed upon the furnace crown of an internally fired boiler, and also that an *efficient* blowing-out apparatus would have *prevented the accumulation* in a great measure, if not alto-

gether, and thus that the explosion was due to the dangerous character common to all externally-fired boilers, coupled in this case with neglect.

At another meeting of this association the report for the month of July was presented by the chief engineer, of which the following is an abstract:—

“During the past month there have been examined 324 engines and 450 boilers. Of the latter, 17 have been examined specially, 11 internally, 55 thoroughly, and 367 externally, in addition to which 3 of these boilers have been tested by hydraulic pressure. The following defects have been found in the boilers examined:—Fracture, 8 (2 dangerous); corrosion, 16; safety valves out of order, 9 (2 dangerous); water gauges ditto, 21; pressure gauges ditto, 8; blow-out apparatus ditto, 37; fusible plugs ditto, 2; furnaces out of shape, 4; over pressure, 1 (dangerous); deficiency of water, 1 (dangerous); blistered plates, 3; total, 110 (6 dangerous). Boilers without glass water gauges, 2; without blow-out taps, 38; without back-pressure valves, 41.

“It is gratifying to find that the number of ‘thorough’ examinations of boilers, though not high during the past month, is steadily increasing. During the month ending June 26th last, as many as 104 were made, in addition to 12 ‘internal’ and 10 ‘special,’—making 126, independently of the ordinary ‘external’ examinations. This number is a greater one than has been reached in any previous month.

EXPLOSIONS.

“One explosion has occurred during the last month, of a very fatal character, particulars of which are given below. The following is the monthly tabular statement:—

TABULAR STATEMENT OF EXPLOSIONS

FROM JUNE 27TH, 1863, TO JULY 24TH, 1863, BOTH INCLUSIVE.

Progressive No. for 1863.	Date.	General Description of Boiler.	Persons killed.	Persons injured.	Total.
No. 20.	June 27	Ordinary double flue or ‘Lancashire,’ internally fired,	10	4	14

"No. 20 explosion, by which ten persons were killed and four others injured, occurred to an ordinary mill boiler of the two-flued 'Lancashire' class. This boiler was not under the inspection of this association.

"The dimensions were as follow:—Length, 30 feet, diameter of the shell nearly 7 feet 6 inches, and that of the furnace tubes—which were parallel throughout, and not strengthened by any hoops or flanges—2 feet 8 inches; the thickness of the plates in the shell and tubes, seven-sixteenths, in the flat end plates half an inch, each of them being strengthened with three gusset stays, secured with double angle irons.

"The longitudinal seams in the shell were not laid in line, but disposed so as to break joint. The age of the boiler was about two years. It had not been tested by hydraulic pressure.

"The boiler had been fitted with a single lever safety-valve, the valve being inclosed in a box bonnetted over from which the waste steam escaped through a discharge pipe, carried through the wall of the boiler house. It had also been fitted with a glass water gauge—a feed-check and back-pressure valve combined, fixed to the front end plate, a little below water level—a blow-out or mud tap, and a steam pressure gauge, of the dial class; but the boiler had no tap for fixing an indicator, so as to check the accuracy of the gauge, and ascertain the actual working pressure with the steam up.

"The boiler was rent into so many fragments by the explosion that it was completely destroyed, while considerable damage was also done to the surrounding property. Both the furnace tubes were torn away from the end plates, as well as separated into two pieces, dividing at one of the transverse seams at the middle of their length. Three of these lengths, weighing upwards of a ton each, were blown over a row of cottages, one alighting on the first floor of a dwelling beyond, having broken through the roof in its fall, the other two lengths falling at intermediate distances between these two row of buildings; while the fourth flew in a direction nearly at right angles with the others, and also fell upon a cottage carrying in the roof. The safety-valve weight, which was a ball of about 8 inches diameter, was shot upwards, and, on its fall, broke through the roof of a third cottage. The shell of the boiler had been torn up into so

many small pieces that it was difficult to trace the course of the rents, and to determine where they had first commenced; but it may be remarked that one of them ran through the manhole, which was not strengthened as it should have been by a substantial mouthpiece. These fragments of the shell had not flown so far as the flue tubes had done, but many of them lay scattered near the original seat of the boiler, while some were buried under the ruins. The end wall of the mill was blown down, and the various floors laid open, while the engine was completely buried in the *debris*. The chimney was gashed by a large rent, running up it for half its height, and stood tottering over the old seat of the boiler, so that approach was dangerous; while the ground surrounding was covered with bricks, and the ruins of the injured buildings; the windows in every direction, as well as many of the roofs, being riddled. But it is difficult to convey an adequate idea of the ruin that had been produced.

"The cause of the explosion has twice been investigated before a coroner's jury, conducted in each instance by a different coroner on account of the localities in which the deaths occurred. Scientific evidence was given in each case. At the first trial, one scientific witness gave it as his opinion that there were no traces of there having been any deficiency of water, but that the safety-valve had been deranged and inoperative; while at the second trial, another scientific witness thought that the safety-valve had worked quite 'glibly,' and that shortness of water had caused the explosion. A verdict of accidental death was brought in in each instance.

"With regard to the explosion having arisen from shortness of water, it was given in evidence at the inquest that the gauge glass was blown through, and plenty of water observed shortly before the explosion happened; the correctness of which was borne out by subsequent examination, since the flues were found to be coated with incrustation, which over-heating, had it occurred, would have disturbed; while, in addition, the furnace crowns could not have retained their shape as they did, had the water been low.

"As to the explosion being due to excessive pressure consequent upon the defect of the safety valve, it is true that the spindle of *the valve was bent*, but it is a matter of opinion whether this

did not become so subsequently to the explosion, and was its consequence rather than its cause. At the time of making my own examination, which was done immediately on the explosion being reported, there was no opportunity of seeing the safety valve, since it was in the hands of the jury who were then engaged upon the inquest; but I am informed, on good authority, that the injury was such as could not have occurred to the valve in regular work, while it was known to have been previously in good order.

"But, apart from the condition of the safety valve there are other considerations affecting the view that the explosion was due to excessive pressure alone. There was no evidence to prove that the pressure exceeded 60 lb. per square inch, and neither that nor twice the amount would have rent the shell had the material and workmanship been good; while from the fact that the flue tubes were not collapsed, and the shell was rent into fragments—although the latter should have resisted twice the strain of the former—it is clear that the explosion did not result from simple over pressure.

"It cannot be doubted that the plates were of very bad quality, one of them in the shell, situated at the top of the external flue, had fractured through the solid when the boiler was at work a few months since, while it is reported that one of the scientific witnesses, who gave evidence at the inquest, stated that merely with the blow of a brick he had broken off a piece of plate about 15 or 16 square inches in area, and seven-sixteenths in thickness. Also, another engineer, who had an opportunity of fully examining the plates after the inquest was closed, has informed me that he found them to be very inferior, while a specimen kindly forwarded to me, at my request, by the owner of the boiler, shows a short and crystalline fracture, is little better than cast-iron, and quite unfit for use. The cast-iron nature of the plates rendered them less adapted to withstand the tensile strain of the shell than the compressive one of the furnace tubes, which therefore accounts for the shell having been broken up into pieces, while the furnace tubes were uninjured, except by the effects of the explosion itself."

The following practical remarks from the report of the Manchester Association will be useful:—

SETTING BOILERS.

"Considerable irregularity is met with in the manner in which many of the boilers under inspection are set. The external brickwork flues of some are so contracted as to be altogether inaccessible, so that no examination of the plates can be made; of others, the side flues are of very unequal area, thus unfairly diverting the draught; of others, again, they are carried dangerously high, being considerably above the low water level; while in some cases longitudinal seams of rivets run right along the bearing surface of the brickwork seating, which not only accelerates corrosion of the plates should leakage take place, but at the same time conceals the injury so that it frequently goes on to a dangerous extent undetected.

"Careful particulars are taken of the mode in which all the boilers under inspection are set, and it is thought that a statement of the dimensions found to be of the best proportions, and now generally adopted, would be of service to the members, and tend to prevent the recurrence of the irregularities and inconvenience referred to above.

MODE OF SETTING AN INTERNALLY FIRED BOILER OF 7 FEET DIAMETER.

"The boiler to be carried on two continuous side walls, spaced 4 feet apart in the clear between them. The top course of these walls on which the boiler rests to consist of fire-brick blocks, which can be obtained of any desired pattern, and should, in the present instance, be of the following dimensions:—Height on the vertical face, 12 inches; width on the base, 12 inches; width of bearing surface on which the boiler beds, 5 inches. The angle of this surface, in order to fit the circle of the boiler, should be 38 degrees above the horizontal; this will be best obtained by striking it out full size in accordance with the foregoing dimensions, which can readily be done by any competent bricksetter. The back of the blocks should slope down to a thickness of $4\frac{1}{2}$ inches, so as to form an abutment against the brickwork at the bottom of the side flues, to prevent the weight of the boiler *thrusting* the blocks apart. The top of the side flues to be on a *level with the furnace crowns*, and the bottom on a level with

the underside of the boiler. Their width at the top to be 6 inches, thus making a distance of 8 feet in the clear between the face of the side flues, which should not follow the sweep of the boiler, as is frequently the case, but should run vertically from top to bottom, in order to form a pocket for deposit to lie in without covering any of the heating surface of the boiler, and at the same time to leave room for a man to pass along and examine the plates. The flue beneath the boiler will be formed by the side walls already referred to, spaced 4 feet apart; the height may be about 2 feet, but this is not very material so long as sufficient room is allowed for convenient access. The course of the flame immediately after leaving the furnace tubes, to pass under the bottom of the boiler; to split at the front end and return to the chimney through the two side flues. Generally two dampers are introduced, one to each side flue. It is important in boilers with two plain internal flue tubes, that the course of the flame should pass under the bottom before entering the side flues, in order to promote circulation of the water, and to prevent straining the boiler at the transverse seams of rivets on its under side, and causing what is familiarly known as 'seam rending.'

"It is not equally necessary, though still advisable, to pass the flames under the bottom before entering the side flues of those boilers which are fitted with tubes or pockets for quickening the circulation of the water.

"In cases where the angle iron at the front end plate is external, the face of the brickwork should be set back some inches, so that the angle iron may be exposed to view, or leakage may take place without detection. The front cross wall underneath the boiler need not be more than $4\frac{1}{2}$ inches thick, otherwise it is frequently found to harbour corrosion. This wall should be recessed so as to leave the blow-out pipe entirely free, in order that it may be accessible to examination, not liable to be strained by settlement of the boiler, nor corrosion of the plates accelerated by contact with the brickwork should leakage occur.

"All the external flues should be faced with fire-brick, and set in fire clay, no mortar being allowed to touch the boiler, especially below water line.

MODE OF SETTING INTERNALLY FIRED BOILERS OF 6 FEET AND 5
FEET DIAMETER.

"The general arrangement of flues should be the same as that given above for a boiler of 7 feet diameter, and a slight alteration only made in detail to allow for the difference in size.

"For a boiler 6 feet in diameter, the side walls should be spaced 3 feet apart in the clear. The fire-brick blocks should be $12\frac{1}{2}$ inches high on the vertical face, 12 inches wide on the base, and 4 inches upon the bearing surface upon which the boiler beds, the angle of this surface above the horizontal being 33 degrees, the other dimensions of these blocks remaining as before. The side flues to be carried down 3 inches below the level of the bottom of the boiler, and at the top to be on a level with the furnace crowns, this latter, as well as the remaining particulars, being the same as those for the boiler of 7 feet diameter.

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"For boilers of still smaller diameter if a mid-feather be unavoidable, it should be faced with fire-brick blocks for the boiler to rest on, and the blocks bevilled off to a narrow bearing surface, since one of the causes of injury from mid-feather walls, is their width. For a boiler of 4 feet diameter, the width upon the top edge need not exceed 3 inches. The flues under all circumstances must be sufficiently large to admit of a man's passing right through them for the purpose of examination."

Another association has been of late originated in Wolverhampton for the purpose of assuring and inspecting boilers, and called the "Midland Steam Boiler Assurance and Inspection Company." A meeting of this association was held at their offices, Wolverhampton, when a report for the past half year

was submitted by E. Martin, chief engineer. The following is an abstract:—

“I have the honour to report that, up to the end of 1862, particulars were taken of 2,245 boilers with a view to inspection or assurance, and that proposals were accepted for the inspection of 404 and the assurance of 366, making a total of 770 boilers placed under the care of the company. This number has since been increased to 1,001. The 770 boilers under inspection and assurance may be described under the four following heads:— 1st. Plain cylindrical with round egg-shaped elliptical or hemispherical ends, and sometimes with one or more internal flues, through plain or breeches tubes, but all fired under the bottom, 432; 2d. Furnace boilers worked by the waste heat from the puddling, heating, refining, charcoal or coking furnaces, either upright or horizontal, with one or more internal tubes, 162; 3d. Cornish or Fairbairn boilers, with cylindrical shells and one or more tubes, internally fired, 100; 4th, Low-pressure boilers, either balloon, haystack, Butterley, or wagon, with one or more flue tubes, 76; total 770. Among the purposes for which these boilers were used are colliery engines for pumping, and 227 are colliery engines for winding; total colliery engines, 298; mills and forges, 269; blast furnaces, 109; pumping engines at canals and waterworks, 41; lathe engines, 21; clay mills, 18; and for other purposes, 14, half of which were boilers at saw mills. The colliery and blast engine boilers are often placed in groups of from two to six, and the mill and forge furnaces are generally in groups of from five to thirty connected together, which greatly facilitates the safe working of furnace boilers. All boilers under the inspection of the company, whether for inspection or assurance, are subjected to the same examination, which is either external, internal, or thorough, according to the facilities given. The external examination is made at any time when the boiler is working; the internal is made when the boiler is cold and empty; and the thorough only when the flues are properly cleansed and prepared. There have been made during the half year ending December 31, 1862, 868 external, 85 internal, and 52 thorough examinations, making a total of 1,003. No difficulty has been experienced in making the examinations, as masters and enginesters give all the help they can, and your inspectors take care

to avoid causing inconveniences or needless trouble. It has been necessary to report some boilers as in a dangerous condition, and in all cases the repairs or renewal recommended has been speedily and willingly done. In some cases needless expenditure has been prevented by the reports of the result of the examination. The chief points needing attention in the working of boilers under inspection are frequent cleaning, as the water of the district scurfs a good deal, and is apt to cause the burning of the plate over the fire. This fault in the water is, perhaps, less to be dreaded than corroding, as by cleaning the boiler can be restored to its original condition, while corrosion produces a permanent injury. Safety valves are generally found over-weighted. Pressure gauges are often out of order, and therefore worse than nothing, as they lead to false confidence. Glass water gauges are much neglected, dependence being placed on the float alone. The feed is generally regulated by hand, although self-acting apparatus may be attached to the boiler. Blow-off cocks are frequently neglected or disused, which leads to much extra trouble in cleaning, and not unfrequently to danger. Screw-patches on the old-fashioned low-pressure boilers are sometimes causes of great injury and weakness to the boiler, especially when the patch is so small as to have only one bolt in the centre. The brick covering of boilers to prevent radiation often causes much corrosion on the shell of the boiler, by being allowed to get out of repair, so that the wet gets in, in which case it is worse than none. Too little boiler power is a frequent cause of difficulty and danger, as sufficient time cannot be spared for repairs or cleaning, so that when one boiler is off others have to be fired too hard. The great objects to be aimed at is to have boilers of good material and workmanship, of suitable construction for the work it has to perform and the pressure it has to bear, and just enough fittings of the least complicated kinds to enable the attendants to know the exact height of the water and the pressure of the steam. I would call attention to the great importance and utility of a periodical application of the hydraulic test as the surest and least injurious means of detecting faults which would otherwise escape notice. A suitable apparatus for this purpose is kept by the company. During the past year thirty-five explosions have been reported, but I will mention only the six explo-

sions in this neighbourhood, and I am happy to report that none of them are boilers under the inspection of the company. Three were balloon boilers, which burst for want of stays; one Cornish boiler from collapse of tubes; one furnace boiler from the same cause, and one upright firing boiler from collapse of the internal fireplace. In the two latter cases the boilers were of defective construction, and the explosion was caused by unusual pressure, owing to delay for repairs in the steam hammers which they worked. Both reports were received and adopted, the retiring directors and auditors were re-elected, and the chairman and the other members of the board of directors were thanked.—The chairman, in responding, spoke highly of the engineer and the secretary, and said he hoped that, by the extended operations of the company, the number of boiler explosions in this district would be lessened."

This company held another half-yearly meeting at their offices, Wolverhampton, when Mr. Edward B. Martin, engineer, presented his report for the half-year ending June 30th, 1863, of which the following is an abstract from the "Engineer:"—

"The engineer's report stated that during the half-year ending June 30th last, particulars were obtained of 371 boilers, with a view to proposal for inspection or assurance, which, with those before reported, made a total of 2,616. Proposals had been accepted, during the six months, for the inspection of 215 and the assurance of 134, making together 349 boilers. The total number of boilers under inspection up to June 30th was 619, and under assurance 500, making 1,119 boilers under the care of the company. That number had now been increased to 1,184. The boilers were of the following descriptions:—Plain cylindrical, externally fired, 670; furnace boilers, of various shapes, 235; Cornish or others, internally fired, 126; low-pressure balloon or wagon-shaped, 88; total, 1,119. These boilers were employed as follows:—Colliery engines for pumping, 95; ditto for winding, 324; mills and forges, 423; blast furnaces, 171; canals, water and gas works, 43; lathe engines, 22; clay mills, 22; saw mills, 7; rope works, 4; flour mills, 3; locomotives, 2; stamping, 3; total, 1,119. All boilers had been subjected to the same careful inspection, and, wherever opportunity could be given, they had been examined internally and in the

flues. There had been made during the half-year 1,986 external, 163 internal, and 337 thorough—in all 2,486 examinations, and both masters and engine tenters had given every facility for these examinations. As the system of inspection became better known still greater benefit would, it was hoped, accrue to those who placed their boilers under the care of the company. Fifty-five reports had been sent to owners as to matters requiring attention, and the recommendations had been speedily carried out. Care had been taken to avoid causing needless trouble or expense. The chief points reported on had been as follow:—

Alteration of shape from the insufficiency or want of proper stays, or from undue heating, or careless usage, or from injury by accumulation of scurf, or blistering of plates. The strength of the shells of boilers was frequently found greatly diminished by inefficient repair, especially from the use of little narrow patches over cracks on the edges of plates, which might effectually prevent leaking for a time, but which leaves the plate little, if any, stronger than it would be with the crack untouched. Many of these patches have been found on a single plate, and they seldom last long, as they burn off because the water cannot reach them. Safety valves are very frequently found overweighted, either from inadvertence, or to prevent leaking when the valve requires 'scouring.' These valves are of little use unless they are so adjusted as to lift freely at a few pounds above the ordinary working pressure, so as to give complete relief before the pressure can rise to an unsafe height. Much danger would be avoided if the practice were more common of having a valve near each engine, of sufficient size to let off as much steam as that engine usually takes, and within easy access of the man in charge to open when there is a 'stand.' Safety valves are also sometimes overweighted to make an engine that is out of repair do its required work. Attention having been called to this point in reports, has led to engines being worked with considerably less pressure of steam, thereby effecting great economy. Pressure gauges of all kinds are frequently found out of order and indicating falsely, but this is more often from unfair usage than from any defect in their principle or construction. They are sometimes placed on the steam pipes, and so close to the engine that they vibrate with every stroke, to the great injury of their delicate

mechanism. Placed in this position they often give but an approximate indication of the pressure in the boilers, because the steam has been drawn through long ranges of exposed pipes of small diameter. All gauges should be as near as possible to the boiler, so as to indicate the pressure at which the steam is 'raised,' not that at which it is used. A good gauge, kept in perfect repair, frequently applied to each boiler at taps placed for that purpose, and the safety valves adjusted by it, would often be a greater safeguard than gauges left constantly in exposed positions. Glass gauge tubes can seldom be kept in order in ironworks, being so liable to breakage. Floats are often universal, many boilers being fitted with two, but they are too frequently found working badly. Scurf is found in almost all boilers in this district, varying in thickness and composition. Scurf is only of consequence on those parts of the boiler exposed to heat. Needless injury to plates and rivets is frequently caused by too vigorously chipping to get it off. The plates near the fire, however, cannot be kept too carefully cleaned. Blowpipes would very much mitigate the evils of scurfing if they were more frequently used, especially in plain cylinder boilers, and those with fire under them. Corrosion is seldom met with on the inside of boilers in this district, but is a most frequent cause of injury on the outside from the leaking of the steam pipes and fittings. Thinning of plates from this cause has been most frequently reported both above and beneath the brickwork, and in many cases to a dangerous extent. In all reports attention is called to anything that is observed to lead to injury or expense, as well as to anything causing present danger. There have been twenty-one explosions in various parts of the country since the beginning of 1863. Five of these had been personally examined and reported on by the engineer of this company. They were as follows:—A plain cylindrical boiler, with round ends, exploded from rupture over the fire, having been weakened by too frequent and inefficient repair. A breeches tube from the same cause; a plain cylinder, with round ends, from burning of plate over the fire owing to accumulation of scurf; a plain cylinder from overheating through shortness of water; a two-tube internally fired from undue pressure."

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“I have the honour to report that, up to the end of 1862, particulars were taken of 2,245 boilers with a view to inspection or assurance, and that proposals were accepted for the inspection of 404 and the assurance of 366, making a total of 770 boilers placed under the care of the company. This number has since been increased to 1,001. The 770 boilers under inspection and assurance may be described under the four following heads:— 1st. Plain cylindrical with round egg-shaped elliptical or hemispherical ends, and sometimes with one or more internal flues, through plain or breeches tubes, but all fired under the bottom, 432; 2d. Furnace boilers worked by the waste heat from the puddling, heating, refining, charcoal or coking furnaces, either upright or horizontal, with one or more internal tubes, 162; 3d. Cornish or Fairbairn boilers, with cylindrical shells and one or more tubes, internally fired, 100; 4th, Low-pressure boilers, either balloon, haystack, Butterley, or wagon, with one or more flue tubes, 76; total 770. Among the purposes for which these boilers were used are colliery engines for pumping, and 227 are colliery engines for winding; total colliery engines, 298; mills and forges, 269; blast furnaces, 109; pumping engines at canals and waterworks, 41; lathe engines, 21; clay mills, 18; and for other purposes, 14, half of which were boilers at saw mills. The colliery and blast engine boilers are often placed in groups of from two to six, and the mill and forge furnaces are generally in groups of from five to thirty connected together, which greatly facilitates the safe working of furnace boilers. All boilers under the inspection of the company, whether for inspection or assurance, are subjected to the same examination, which is either external, internal, or thorough, according to the facilities given. The external examination is made at any time when the boiler is working; the internal is made when the boiler is cold and empty; and the thorough only when the flues are properly cleansed and prepared. There have been made during the half year ending December 31, 1862, 868 external, 85 internal, and 52 thorough examinations, making a total of 1,003. No difficulty has been experienced in making the examinations, as masters and engineers give all the help they can, and your inspectors take care

to avoid causing inconveniences or needless trouble. It has been necessary to report some boilers as in a dangerous condition, and in all cases the repairs or renewal recommended has been speedily and willingly done. In some cases needless expenditure has been prevented by the reports of the result of the examination. The chief points needing attention in the working of boilers under inspection are frequent cleaning, as the water of the district scurfs a good deal, and is apt to cause the burning of the plate over the fire. This fault in the water is, perhaps, less to be dreaded than corroding, as by cleaning the boiler can be restored to its original condition, while corrosion produces a permanent injury. Safety valves are generally found over-weighted. Pressure gauges are often out of order, and therefore worse than nothing, as they lead to false confidence. Glass water gauges are much neglected, dependence being placed on the float alone. The feed is generally regulated by hand, although self-acting apparatus may be attached to the boiler. Blow-off cocks are frequently neglected or disused, which leads to much extra trouble in cleaning, and not unfrequently to danger. Screw-patches on the old-fashioned low-pressure boilers are sometimes causes of great injury and weakness to the boiler, especially when the patch is so small as to have only one bolt in the centre. The brick covering of boilers to prevent radiation often causes much corrosion on the shell of the boiler, by being allowed to get out of repair, so that the wet gets in, in which case it is worse than none. Too little boiler power is a frequent cause of difficulty and danger, as sufficient time cannot be spared for repairs or cleaning, so that when one boiler is off others have to be fired too hard. The great objects to be aimed at is to have boilers of good material and workmanship, of suitable construction for the work it has to perform and the pressure it has to bear, and just enough fittings of the least complicated kinds to enable the attendants to know the exact height of the water and the pressure of the steam. I would call attention to the great importance and utility of a periodical application of the hydraulic test as the surest and least injurious means of detecting faults which would otherwise escape notice. A suitable apparatus for this purpose is kept by the company. During the past year thirty-five explosions have been reported, but I will mention only the six explo-

sions in this neighbourhood, and I am happy to report that none of them are boilers under the inspection of the company. Three were balloon boilers, which burst for want of stays; one Cornish boiler from collapse of tubes; one furnace boiler from the same cause, and one upright firing boiler from collapse of the internal fireplace. In the two latter cases the boilers were of defective construction, and the explosion was caused by unusual pressure, owing to delay for repairs in the steam hammers which they worked. Both reports were received and adopted, the retiring directors and auditors were re-elected, and the chairman and the other members of the board of directors were thanked.—The chairman, in responding, spoke highly of the engineer and the secretary, and said he hoped that, by the extended operations of the company, the number of boiler explosions in this district would be lessened."

This company held another half-yearly meeting at their offices, Wolverhampton, when Mr. Edward B. Martin, engineer, presented his report for the half-year ending June 30th, 1863, of which the following is an abstract from the "Engineer:"—

"The engineer's report stated that during the half-year ending June 30th last, particulars were obtained of 371 boilers, with a view to proposal for inspection or assurance, which, with those before reported, made a total of 2,616. Proposals had been accepted, during the six months, for the inspection of 215 and the assurance of 134, making together 349 boilers. The total number of boilers under inspection up to June 30th was 619, and under assurance 500, making 1,119 boilers under the care of the company. That number had now been increased to 1,184. The boilers were of the following descriptions:—Plain cylindrical, externally fired, 670; furnace boilers, of various shapes, 235; Cornish or others, internally fired, 126; low-pressure balloon or wagon-shaped, 88; total, 1,119. These boilers were employed as follows:—Colliery engines for pumping, 95; ditto for winding, 324; mills and forges, 423; blast furnaces, 171; canals, water and gas works, 43; lathe engines, 22; clay mills, 22; saw mills, 7; rope works, 4; flour mills, 3; locomotives, 2; stamping, 3; total, 1,119. All boilers had been subjected to the same careful inspection, and, wherever opportunity could be given, they had been examined internally and in the

flues. There had been made during the half-year 1,986 external, 163 internal, and 337 thorough—in all 2,486 examinations, and both masters and engine tenters had given every facility for these examinations. As the system of inspection became better known still greater benefit would, it was hoped, accrue to those who placed their boilers under the care of the company. Fifty-five reports had been sent to owners as to matters requiring attention, and the recommendations had been speedily carried out. Care had been taken to avoid causing needless trouble or expense. The chief points reported on had been as follow:—Alteration of shape from the insufficiency or want of proper stays, or from undue heating, or careless usage, or from injury by accumulation of scurf, or blistering of plates. The strength of the shells of boilers was frequently found greatly diminished by inefficient repair, especially from the use of little narrow patches over cracks on the edges of plates, which might effectually prevent leaking for a time, but which leaves the plate little, if any, stronger than it would be with the crack untouched. Many of these patches have been found on a single plate, and they seldom last long, as they burn off because the water cannot reach them. Safety valves are very frequently found overweighted, either from inadvertence, or to prevent leaking when the valve requires 'scouring.' These valves are of little use unless they are so adjusted as to lift freely at a few pounds above the ordinary working pressure, so as to give complete relief before the pressure can rise to an unsafe height. Much danger would be avoided if the practice were more common of having a valve near each engine, of sufficient size to let off as much steam as that engine usually takes, and within easy access of the man in charge to open when there is a 'stand.' Safety valves are also sometimes overweighted to make an engine that is out of repair do its required work. Attention having been called to this point in reports, has led to engines being worked with considerably less pressure of steam, thereby effecting great economy. Pressure gauges of all kinds are frequently found out of order and indicating falsely, but this is more often from unfair usage than from any defect in their principle or construction. They are sometimes placed on the steam pipes, and so close to the engine that they *vibrate with every stroke*, to the great injury of their delicate

mechanism. Placed in this position they often give but an approximate indication of the pressure in the boilers, because the steam has been drawn through long ranges of exposed pipes of small diameter. All gauges should be as near as possible to the boiler, so as to indicate the pressure at which the steam is 'raised,' not that at which it is used. A good gauge, kept in perfect repair, frequently applied to each boiler at taps placed for that purpose, and the safety valves adjusted by it, would often be a greater safeguard than gauges left constantly in exposed positions. Glass gauge tubes can seldom be kept in order in ironworks, being so liable to breakage. Floats are often universal, many boilers being fitted with two, but they are too frequently found working badly. Scurf is found in almost all boilers in this district, varying in thickness and composition. Scurf is only of consequence on those parts of the boiler exposed to heat. Needless injury to plates and rivets is frequently caused by too vigorously chipping to get it off. The plates near the fire, however, cannot be kept too carefully cleaned. Blowpipes would very much mitigate the evils of scurfing if they were more frequently used, especially in plain cylinder boilers, and those with fire under them. Corrosion is seldom met with on the inside of boilers in this district, but is a most frequent cause of injury on the outside from the leaking of the steam pipes and fittings. Thinning of plates from this cause has been most frequently reported both above and beneath the brickwork, and in many cases to a dangerous extent. In all reports attention is called to anything that is observed to lead to injury or expense, as well as to anything causing present danger. There have been twenty-one explosions in various parts of the country since the beginning of 1863. Five of these had been personally examined and reported on by the engineer of this company. They were as follows:—A plain cylindrical boiler, with round ends, exploded from rupture over the fire, having been weakened by too frequent and inefficient repair. A breeches tube from the same cause; a plain cylinder, with round ends, from burning of plate over the fire owing to accumulation of scurf; a plain cylinder from overheating through shortness of water; a two-tube internally fired from undue pressure."

Perhaps *some apology is necessary* for the great length of the

foregoing reports; these, however, comprise only a very small portion of the experience of this valuable association; and when we consider the immense importance of past failure to the future success of any pursuit, apology will so far be unnecessary.

Recapitulatory Remarks on Boiler Explosions.—The cause of boiler explosions may be briefly recapitulated as follows:—First, from original faulty construction; and secondly, from careless attendance. Under the first cause not only is the construction and design of the boiler involved; but also the efficiency of all mountings, &c., for the purpose of indicating the internal condition of the boiler. The *safety-valves* should be of sufficient area to carry off all the steam capable of being generated by the boiler, and on no account should stuffing boxes, or even glands, be fitted to the spindle of the safety-valve, unless considerable play be allowed for such. Another common source of annoyance in safety-valves, and a frequent cause of accident, is the sticking of the lever in its joint. Frequently such levers are made a good fit in the joint as also the pin; the consequence is, that in blowing off once or twice, the joint gets rusted, as also the pin, and we have frequently seen the whole force of a man applied to the end of a two-feet lever, and without being able to raise it. It is not to be wondered then, that with the addition of the weight or spring balance upon a lever fast in its joint, that excessive pressure should be generated in the boiler and explosion inevitably follow. Now this joint not only seizes the pin, but also the sides of the lever, so that we have sometimes found it necessary to introduce brass washers between the sides of the joint, while a hard brass pin was passed through the joint. This plan effectually prevents the lever being held fast by rust or any other cause. Perhaps a better plan still, although not the most elegant, is to make the joint similar to the seat for the fulcrum of a pair of scales, while a wedge-shaped steel fulcrum is keyed fast in the end of the lever. In such a case there is no chance of the lever getting fast, while the friction is reduced to a minimum, and the balance most perfect. Too much care cannot be bestowed upon safety-valves, considering the vital necessity there is to have such appliances to ensure the safety of the boiler.

Another fruitful source of accidents, as already illustrated in *the reports of the Manchester Association*, is a deficiency in the

water supply; this, in due course, brings us to the consideration of the apparatus designed to indicate the state of the water-level in steam boilers.

There are many and various forms of such apparatus, the most common being the gauge-glass. On this subject we cannot do better than quote the following able article from the *Mechanics' Magazine*:—"Although it is quite certain that a red-hot fire-box cannot generate sufficient steam to explode a boiler, it is equally certain that any over-heating due to too low a water-level, is not only injurious, but, if often repeated, absolutely destructive to either the bottom plates of a boiler, or the top of a fire-box, as the case may be; hence a few words on the best means of ascertaining, at all times, the precise level of the water within a boiler, may not prove uninteresting.

"Were it possible to construct a boiler of glass, many phenomena doubtless, connected with the relative generative powers of different regions of the boiler, the mode in which priming takes place, the deposit of sediment, &c., would become so evident to a careful observer, that many useful deductions might be drawn from the information so gained; but as boilers are invariably constructed of opaque materials, all information regarding the state of affairs within, must be described from sources more or less indirect. A patent has, it is true, been taken out for the application of a powerful lens—or telescope, in fact—by means of which the observer, aided with a strong light cast within the boiler, by a lamp and a second lens, can wholly or partially learn all that goes on within; such an invention not being likely to meet with very general adoption, we need not dwell further on its merits or demerits, but turn to those water-gauges met with in daily use.

"The first we have any mention of in the history of the steam engine is the single gauge-cocks, first applied by Savery in the year 1698. Its application was sufficiently obvious—it was merely making a hole in the side of a vessel through which water would flow when it had reached it. Shortly afterwards Savery employed two of these cocks in order that the water level might be ascertained with greater accuracy. These gauge-cocks are in use to the present day, but, in our opinion, frequently do more harm than good; it is almost impossible, when the steam is of any

considerable pressure, to ascertain whether water or steam escapes from them. Water, by its contained heat, is almost instantly dissipated in spray and steam when the lower cock is opened; and as it always rises to any opening near its level, the upper cock will discharge it plentifully, even though the real water-level is at the instant several inches below it; hence they are almost totally useless for tubular boilers, unless we adopt some such arrangement as that employed by Mr. Gooch in some of his locomotives. He affixed a brass tube of small diameter to the boiler in exactly the same way that a glass gauge is fitted; into this tube the gauge-cocks are screwed. In order to test the level of the water, open both cocks communicating with the vertical pipe for a few minutes, then close them, and open a small cock on the top of the tube, which will discharge the steam contained in it; then, on opening the gauge-cocks, the exact level of the water within the tube, and of course within the boiler, may be ascertained with certainty, as the water issues quietly by its own gravity from the gauge-cocks.

"The ordinary gauge-cocks may sometimes be applied with propriety to large boilers without inside flues, as the variation of the water-level through a range of nine or ten inches is seldom of much importance, and in many situations where boilers get little cared for and glass gauges are liable to be broken, they possess a certain amount of value.

"But the most popular gauge for such situations, and indeed the only one used in many parts of England, is the float; only applicable to stationary boilers, of course. This, if properly constructed at first, and treated with moderate care afterwards, we are inclined to consider second to none; its cleanliness, and the large range of indication which it gives, render it an extremely valuable instrument; but, when badly constructed and neglected for long periods, it is undoubtedly more likely to give false indications than the glass water-gauge. The most usual arrangement is a stone float suspended from a wire, which, passing through a stuffing-box, is attached to a small chain, which runs over a light iron pulley, a foot or more in diameter—the other end of the chain carrying a weight which partly balances the stone within the boiler, so as to keep it floating; but as the stone is *seldom very large*, and acts directly on the wire, it is very easy,

by screwing the gland of the stuffing-box too tight, to render it altogether inoperative. The use of iron wire in such a situation will also be certain to induce corrosion, and the consequent destruction of the stuffing in the box.

"The proper method of fitting a float is undoubtedly the following:—Let a lever of considerable length be hung on a fulcrum within the boiler; one end of this lever must be so bent as to reach above the water-level, and must carry a cast-iron ball, sufficiently heavy to balance enough of the weight of a float, moulded and burned in hard brick, fixed to the other end, that it shall be only half immersed in the water. Outside the boiler a light index lever must be fitted, to the short end of which a fine brass wire is attached, and being passed through a small brass stuffing-box, is fastened to the float lever within the boiler close to the fulcrum; any amount of friction in the stuffing-box can scarcely affect the action of the float, from its powerful leverage; and the light index outside can be made to traverse through a sufficient distance to show the most minute variations in the water-level.

"A very efficient float indicator can also be made by fixing a hollow ball sufficiently strong to stand the pressure, and light enough to float, on the end of a lever, of very considerable length, which will lie parallel to the axis of the boiler. The fulcrum of the lever must consist of a brass ball fitted into a stuffing-box on the boiler end, the lever being prolonged a few inches through the stuffing-box, and attached as before to a suitable index. It would be impossible, from its great leverage, to set this float fast, no matter how tightly the packing might be screwed down, and a good india-rubber stuffing would last many months, owing to the almost inappreciable amount of motion in the ball. Such a gauge would, we have no doubt, be certain in its action, and could scarcely get out of order.

"The most generally applicable of all, is undoubtedly the glass tube, which, for boilers in motion, such as locomotives, marine boilers, &c., is absolutely invaluable. Its mode of application deserves far more attention than it usually receives, the almost invariable practice being to fit it to the fire-box end of boilers, from the belief that there it will show exactly the amount of water over the fire-box, and because practically it is almost the

only place where suitable space can be found for it; but as the water-level is always very unsteady thereabouts, its indications are seldom very accurate, especially if the engine draws its steam from the same end of the boiler. In traction engines, in particular, we have seen the gauge fill and empty many times in a minute from the oscillation of the water, due to a rough road in a great measure. We would recommend the use of two tubes—one extending horizontally from the top of the glass nearly to the forward end of the boiler, where ebullition is least; the other in a similar way from the bottom of the glass. The end of this last should, of course, be suspended exactly at the minimum water-level; and the tube should slope from the gauge the whole way, so that water may not lodge in it and cause a false indication.

“Glass gauges are unhappily very liable to become stopped up, by the connections with the boilers getting filled with sediment; a remedy is not easily found, as any enlargement of the holes in the cocks and connecting-pipes might lead to very serious results should the glass tube burst. Some difficulty, too, is found in getting tubes which will keep clear under a very heavy pressure; we have seen four tubes put in one after another in a locomotive working with 130 lb. steam in the course of an hour, although the same glasses answered admirably in a boiler working with 25 lb. steam; very high-pressure steam dissolves the glass, rendering it dim, soft, and brittle. Green glass tubes are far the best.

“Some makers case their gauge in a slotted brass tube; we do not advocate the practice, none but an awkward fireman will break them by a blow, and they render the tube very difficult to keep clean, besides generally entailing some trouble in replacing or packing them.

“For locomotives, marine, and traction engines, we strongly recommend the use of two glass gauges; the second to replace the ordinary almost useless gauge-cocks. The first gauge should be short, and ritted as we have already proposed; the second, fitted in the usual way, should be of very considerable length, say twenty to thirty inches, with a mark about the middle to show the exact top of the fire-box; in many cases the engineer *may get his water short*—quite out of the ordinary glass in fact

—yet it may be very inconvenient, if not impossible, to stop and draw the fire, and he, depending on the fact that his gauge always so fitted as to just empty when there is still an inch or two of water on the top of his box, may go on until irreparable mischief is done. The second gauge would show exactly how far he might go in such a case with safety. On the other hand, by reaching to the top of the boiler it would show, if his ordinary glass were full to the top, exactly how much steam space he had left. The second glass, too, will prevent the necessity for the replacement of a burst glass until a convenient opportunity, and as both are very unlikely to get stopped up at the same time, will prevent such a mistake as a full glass with an empty boiler—a matter of very common occurrence. The additional expense will be very little, compared with the security and comfort of such an arrangement."

Besides efficient water-gauges, *steam-gauges* are absolutely necessary to the safe working of a steam boiler. These, however, have been fully noticed by the reports of the Manchester Association, and therefore we need not further comment upon them here. The second cause of boiler explosions, namely, inattention of "*engine tenters*" or *firemen*, points to the necessity of not only maintaining a rigid system of watchfulness over the characters and behaviour of such men, but the adoption of simple self-acting apparatus by which the danger of having low water and excessive steam in boilers under their care, should be placed beyond the bounds of possibility. To prevent the first named of these evils a valve, by which either the fire should be extinguished or the steam allowed to escape from the boiler, by preference the former; to prevent the second evil a perfectly efficient safety-valve, which, by means already specified, should neither be liable to stick or permit the possibility of overloading; these are both essential.

The results of boiler explosions are very astounding, and have given rise to several theories respecting the unaccountable force liberated during explosion; we believe, however, the "projectile theory," first explained by Mr. D. K. Clark, to be the one which most fully accounts for such a fearfully rapid generation of power or destructive effect. Without going into this theory in detail, *it may be very fitly illustrated by an exact parallel,*

namely, Giffard's injector, of the action of which probably most of our readers are aware. We all know the excess of power given out by such an instrument over the initial boiler pressure, this being entirely due to the projection of the water at a high speed by the steam, and therefore gaining a considerable momentum.

Having considered this, then the theory of boiler explosions is simple. A large quantity of water exists under say 50 lbs. square inch steam pressure, the temperature of this being nearly 300° Fahr., a fracture in the plates of the boiler containing it takes place, and a portion of this pressure is suddenly relieved, occasioning a corresponding flashing off of a portion of this highly heated water, or—as Mr. Fairbairn has it—"liquid steam," which not only follows up the effect of the first portion of steam, but carries with it a great portion of water, which being a ponderous body, is projected with tremendous force against the sides of the remaining plate, or whatever opposes its course. This may be considered as a sufficiently conclusive, if not amply stated, explanation of the cause of such fearful and disastrous results attending boiler explosions.

Before concluding the subject of boilers, it may be as well to state, that the tendency to increase the working pressure of boilers is decidedly an upward one, and that, therefore, the attention of engineers should be directed to the construction of vessels which shall, with a minimum amount of material, withstand a maximum pressure.

Homogeneous metal or mild steel has recently been much employed as a material designed for the manufacture of boilers, and as far as it has been employed it seems to have yielded good results.

On the subject of high pressures, and steel as a material for boilers, we quote the following from the "Mechanics' Magazine," that on steel being an extract from the "Verhandlungen des Vereins zur Beförderung des Gewerbflusses in Preusser's," by Dinglérn "Polytechnisches Journal;"—

"Boiler explosions have occurred ever since the day water was first boiled in a closed vessel; and boilers will explode, for anything we can see to the contrary, to the end of time. We feel *no hesitation in endorsing* the words of Dr. Alban, and repeat-

ing, that our great guiding principle should be 'so to construct the boiler that its explosion may not be dangerous,' a result easily attained by generating the steam within small tubes, or flat spaces strongly stayed, so that the boiler really consists of an assemblage of small generators, more or less detached and distinct one from the other. By this means, not only is great strength secured, but the quantity of steam and water to be suddenly dispersed is so much reduced that little danger can result from an explosion. The small tubes are invariably the weakest parts of such boilers, and being thin, they open quietly, without flying in pieces; hence none of the destructive results due to the propulsion of heavy masses of metal to great distances can ensue. Boilers of this construction are usually termed 'tubulous,' to distinguish them from 'tubular boilers,' in which, instead of the small tubes containing steam and water, they are made use of as flues to convey the products of combustion to the chimney.

"Very excessive pressures have been raised years ago in these tubulous boilers—pressures, indeed, before which anything we now see in daily use sinks into insignificance. Jacob Perkins has employed a pressure of 500 lb. on the square inch for propelling bullets; Dr. Alban, of Plau, in Mecklenburg, worked an engine in London, many years ago, at a pressure of 1,000 lb. on the square inch with the greatest success. Perhaps the nearest approach we have had to these pressures of late years, was in an engine exhibited at the Agricultural Show at Salisbury in 1857, by Mr. Collinson Hall. This engine was worked at a pressure of 300 lb. to the square inch, and gave an indicated horse-power for each 1.25 lb. of coal consumed per hour. The boiler was, we believe, of the upright tubular class, some 2 ft. 6 in. in diameter, and 6 or 7 ft. high, with a circular fire-box in the lower part, and 40 or 50 vertical flue tubes passing through the water and steam (which last they superheated considerably) to the uptake. The explosion of such a boiler as this would of course be attended with disastrous results if the outside shell gave way. And although such boilers are very compact, and capable of standing very high pressures with safety, yet they are in general so subject to priming, and difficult to clean, deposit settling in a hard mass on the crown of the fire-box, from which it cannot be removed, that their use is seldom or never to be recommended.

Mr. Hall is not, of course, the inventor; it would be difficult indeed to say who is.

"Mr. Martin Benson invented and patented a very good form of high-pressure boiler three or four years ago. As it was brought a good deal before the notice of the public at the time, our readers may perhaps be sufficiently acquainted with it to prevent the necessity of a detailed description, for which we have not space. It consists of a great number of small tubes traversing a vertical fire space; the ends of all the tubes are so connected by a very simple and ingenious arrangement, quite protected from the action of the fire by the side walls, as we may call them, of the fire space, that they become one. A vertical receiver of considerable height and moderate diameter is placed at the side of the generator. A small pump, fixed at the bottom of this, and worked by the engine, forces the water in a continuous current through the tube. Entering at the bottom and passing backwards and forwards through all its windings, it is discharged at the top, mingled with steam, into the upper part of the receiver, or steam chest, where the water, separating from the steam, falls to the bottom, while the steam flows through a suitable pipe to the engine. This boiler is said to have given very good results, but has not hitherto met with much favour, owing to a prejudice against the use of the circulating pump. Whether an injector would better answer the purpose of maintaining a current remains to be proved.

"Mr. Benson's boiler may perhaps be regarded as the best of a class of generators, in which the distinguishing principle is the forcing of water through a continuous coil of tube of small diameter, exposed in whole, or in part, to the action of a furnace. From various causes these boilers have never met with extended adoption.

"Dr. Alban's may be regarded as the type of a far superior class of generator, in which a large flat vessel, with the sides very heavily stayed together, usually called the 'heart,' is made the means of communication between a very large number of tubes, about 4 in. in diameter, and 6 or 8 ft. long; one end of each of these tubes is firmly fixed in the front plate of the heart, which *stands just over the fire door*. The tubes traverse horizontally a *fire space some 6 or 8 ft. high, built of brick on three sides, the*

heart forming the fourth. All the tubes are set on a slight incline from the heart downwards, so that the steam may, by its own levity, rise towards and enter the heart, while the water, by its gravity, flows into the tubes to replace that evaporated. The ends of the tubes furthest away from the heart are stopped by moveable covers, which can be removed to clean the tubes, as at this end they pass through the brick wall of the fire-space, in order that they may expand freely. A simple arrangement of plates in the heart conveys the steam, as soon as it leaves the tubes, to one side, where rising, it passes through a suitable tube into a separator about 12 in. in diameter, and some feet long, placed horizontally on top of the generator, but not exposed to the action of the fire; the water which rises with the steam flows back from this separator through a second pipe, which descends at the other side of the heart, and rising from it re-enters the tubes, and is in part converted into steam as before. This boiler, though very expensive, is an extremely durable and economical generator of steam, from 100 lb. to 300 lb. on the square inch; and the tubes being the weakest part of it, an explosion never leads to any dangerous results, from the reasons already pointed out. It enjoys a very good reputation on the Continent, although, we believe, never yet used in Great Britain.

"A class of boilers much the same in principle but very different in construction, has been gradually creeping into favour of late years. The distinguishing characteristics of this generator are an outside shell, square, oblong, or circular, in horizontal section, according to circumstances, which has a second shell, or fire-box, about 6 in. smaller, placed within it, much as the inside fire-box is fitted in a locomotive. In the bottom of the inside box, which is heavily stayed to the outside shell, is placed the fire-grate, while the upper part is traversed by a number of small tubes feruled into the inside shell at each end; the flame and heated air pass upwards between these tubes to the chimney, which is usually placed directly above.

"This kind of boiler, although cheap, possesses many disadvantages; it is very heavy; it is impossible to clean the tubes without taking out the whole inside box; it is very difficult to keep the tubes tight at the ends; and as it is frequently constructed without any regard to correct principles, it has in addition been

accused of excessive priming, which is likely enough when we consider that the tubes are not only very small, but put in on a dead level, so that a constant contention goes on between the water and the steam—one struggling to get out, the other to get in. The tubes should always be put in on an incline of at least 1 inch to the foot, when the steam will escape quietly from the highest end, while the water will enter quietly at the lowest; a constant circulation is thus kept up, which not only permits the supply of dry steam to the engine, but conduces materially to the durability of the boiler.

“Whether a boiler can be produced which will permit the use of sea water under high pressures, is a question we need scarcely enter on; the success which has attended the introduction of surface condensation rendering such a boiler needless. Still certain mechanical difficulties stand in the way of the general adoption of tubulous boilers on board ship; one of the most important is the difficulty of obtaining room enough for the introduction of a new tube in case of accident. This difficulty is not experienced when introducing an ordinary flue-tube, because such tubes invariably present their ends to the firing space, which is usually 8 ft. or 10 ft. wide; but, owing to difficulties entailed by the position of the uptake, the tubes, when horizontal, must almost unavoidably run parallel with the firing space when the stoke-hole bulk-heads preclude the withdrawal or replacement of the tubes; another, and still more serious objection, is the great height of boiler necessary when tubes 4 in. in diameter are employed. Unfortunately, when of smaller size, they are never durable, being very liable to boil dry for a few seconds, when of course they become overheated, and again cooled down by the rush of the re-entrant water; they are thus soon burned out; large tubes always ‘steam quietly,’ and are found durable enough. In consequence of these difficulties, many boilers have been introduced from time to time, in which the steam and water are contained in a large number of flat-sided vertical spaces, well stayed, and arranged like books on a shelf, spaces being provided between them for the circulation of the flame and heated air. Such boilers are all more or less complicated, heavy, and expensive; and although the principle is *good*, it still requires much improvement before it can be *considered worthy of general adoption*. Marine boilers with vertical

water tubes have met with much favour in America, and seem to deserve the good character they bear. Although horizontal surfaces are invariably the most economical, yet the practical exigencies of marine boiler construction often dictate a recourse to vertical surfaces as most convenient."

For steel as a material for steam boilers the following advantages are claimed. That the same strength can be obtained with less material, and therefore thinner plates. The burning or wasting action of the fire upon thin plates is less than upon thick plates. That the conducting powers of steel consequent upon the thin plates is greater than iron; and, therefore, a larger proportion of water is evaporated per lb. fuel. Our experience of iron tells us that thin plates stand the action of fire much better than thick plates, this being especially borne out by American practice; and therefore steel will be pre-eminently superior in this respect, while it embodies equal strength with the thick iron plates.

In Prussia the particular boiler experimented upon is of the common egg-end shape, without flues; it is 4 Prussian feet in diameter, and is 30 ft. long, inclusive of the spherical ends. There is a steam dome on the boiler, 2 ft. in diameter and 2 ft. high, as also a man-hole, 15 in. in diameter and 10 in. high. The thickness of the plate is one quarter of an inch thick. There is another boiler built in, parallel to the first one; it is exactly similar in every respect, except that the material of which it is made is simply common iron plate, the thickness of which is 0.414 in. Prussian. Each of the boilers works up to a pressure of 65 lb. The cast-steel boiler, however, was successively tried, by means of the hydraulic test, up to pressures of 98 lb., 130 lb., and at last up to 195 lb., without changing its shape in the least degree, and without showing any leakages. The only exception to this was, that two of the rivets slightly "sweated" under the great pressure of thirteen atmospheres, or 195 lb. After both the boilers were fired in a similar way, day and night, for about six months and a half, and at a pressure of $3\frac{1}{2}$ to $3\frac{3}{4}$ atmospheres, they were carefully examined, the steel boiler more especially, during the Whitsuntide holidays, while the works were standing. It was then seen that the cast-steel plates were quite unaffected, even at the places most under the influence of the fire. There appeared, on examination, a remarkably small

amount of incrustation in the cast-steel boiler, as compared with the boiler of common plate. This was ascribed to the fact that the steel boiler generated 25 per cent. more steam than one of common plate. It had been previously noticed, while the boilers were working, that the relative quantities of water changed into steam, in the steel and iron boiler respectively, were as 5 to 4. The impression produced by the above examination was strengthened after the boiler had been in use for a year and a half. At this subsequent examination, made only very lately, the plates, rivets, and the steam-tight qualities of the cast-steel boiler were in a perfect state, and it did not appear that the least injury had been caused by the fire to the plates more immediately under its influence. The small production of incrustation was confirmed every time the boiler was cleaned; while the incrustation was $\frac{1}{8}$ of an inch thick in all the other iron boilers of these works, it was scarcely noticeable in the boiler of cast-steel.

During the recent examination, the quantities of feed water were carefully measured by means of Giffard's injector, and the average of twenty days' work, of twelve hours each, gave the quantity of water converted into steam by the cast-steel boiler as equal to 139.92 cubic feet, and by the ordinary iron plate boiler 112.44 cubic feet. The cast-steel boiler thus evaporates 11.66 cubic feet per hour, while the boiler of common plate only steams off 9.37 cubic feet of water per hour. The ratio of the two above numbers (124.44 to 100) is thus almost exactly equal to the ratio of 5 to 4 obtained in the first experiments. During the same time, the quantity of coal consumed was on an average—for the steel boiler, 2,706 lbs.; and for the iron boiler, 2,772 lbs., for twelve hours; thus with 1 lb. of coal 3.28 lbs. of water were converted into steam in the steel boiler, and only 2.51 lb. of water in the iron boiler. The steam-generating capabilities of the two boilers were thus as 127.49 to 100. The steaming power of the steel boiler being thereby no less than 28 per cent. higher than that of the other. It must be remarked that the amount of water we have referred to one pound of coal does not represent the *absolute*, but rather the strictly *comparative* evaporating powers of the two boilers, because these boilers are not *fired directly*, but by means of the waste gases of some puddling furnaces close by. It is also stated that, in several other iron

boilers, the worn-out iron plates over the fires were replaced by steel plates, and that these have lasted as long as one and two years, while the previous iron plates were often burnt out within six months."

DIVISION SECOND.

STEAM-ENGINES.

THE general application of steam-engines as generators of motive power from the expansive force of steam, has, owing to the widely different nature of their employment, of necessity developed many different forms of engines, which are daily extending themselves. Our space will not allow us to proceed to the consideration of every different class of steam-engines, nor would it at all interest our readers, whom, we presume, are well versed in such rudimentary matter. We will, however, classify this division as follows:—Section first, *Engines applied to propel stationary machinery.* Second, *Locomotive and traction engines.* Third, *Marine engines, or those applied for the propulsion of vessels.*

SECTION FIRST—STATIONARY ENGINES.

The most usual forms of such engines are—"beam," "vertical or crank overhead," and "horizontal." Of the first-mentioned form many are still made at a great first cost, but with a view to ultimate economy in consumption of steam and consequently of fuel. Nearly all such engines are condensing; some of the old "Watt" type, but those of later manufacture are chiefly upon the combined high and low pressure or "M'Naught" principle. In those engines constructed on the latter principle, the high-pressure cylinder is placed intermediately between the low-pressure cylinder (which occupies its original position at the extremity of the beam) and the main centre, either next the low-pressure cylinder or next the crank shaft. The high-pressure cylinder of necessity has a shorter stroke, and is made of a diameter considerably less than the low-pressure cylinder—according to the

initial boiler pressure. The steam is usually "cut off" by either an expansion valve, or, more commonly in the "Lancashire compound engine," by the "double beat" equilibrium valve. This expansion, however, is in only very few instances variable so as to adjust the "cut off" to the work being performed. This, however, in Lancashire is little required, owing to the steadiness with which the cotton machinery is kept at work. In other works, however, this is not always the case, and therefore a good variable expansion valve in communication with the governors would give still better results. The piston speeds of engines of the above-mentioned class are very slow, and consequently such engines are massive and proportionately expensive for a given power. In America they have shown that it is not impracticable to obtain a speed of piston in beam engines equal to 500 feet per minute. We extract the following from the "*Scientific American*," which will give an idea how far piston speed is carried in beam engines:—

"At one period of the science of steam engineering it was the practice to fix the limit of the speed of the piston at so many feet per minute; and from this and the other data usually taken into account—as the area of the piston, pressure of steam, &c.—the horse-power of the engine was calculated. If we are not in error, 250 ft. has been set down as a standard speed for pistons; but modern engineers prefer to drive their pistons as fast as they can with safety, and to disregard rules which experience proves the uselessness of. We have, as a result, the performance of the engine of the 'Golden City' (a new steamer belonging to the Pacific Mail Steamship Company). It is of the beam variety, the beam weighing upwards of 18 tons. This engine has a piston 105 in. in diameter by 12 ft. stroke, and upon a recent engineers' trial trip, achieved the remarkable speed of 420 ft., or $47\frac{1}{2}$ double strokes per minute. We have no doubt that the engine will be able to add materially to this speed, as the machinery was entirely new, it being merely an experimental trip. This is not an isolated case, by any means. The 'City of Buffalo,' formerly a passenger steamer upon Lake Erie, now dismantled for the want of trade, had an engine with a cylinder of 76 in. diameter and 12 ft. stroke, which drove paddle-wheels 34 ft. in diameter, whose floats had 31 in. face,

were 11 ft. long, and had from 36 in. to 40 in. dip— $19\frac{1}{4}$ revolutions, or 39 single strokes per minute. By a severe exercise of mathematical knowledge, we ascertain this to be a piston speed of 468 ft. per minute. We remember these facts and figures very well, as at that time we were pretty much occupied in looking after the engine aforesaid. The beam weighed nearly 16 tons, and was stopped and started 39 times in a minute, working with great ease and certainty. The beam of a beam engine appears to some to be an insuperable obstacle to the general adoption of the class of engines to which it belongs; and its weight, momentum, velocity, &c., are charged heavily to its demerit. These theories, we fancy, are disturbed by the actual facts in the case, which are, that the beam is so poised and balanced on its centre, that the supposed shock of changing its line of motion is utterly neutralized; and as for the weight, that is supported by the framing, and is no more against the power exerted by the piston than the smoke stack. A beam, weighing 15 tons, or 18 tons, can be moved through any portion of its arc of vibration by the strength of a man; providing, of course, that the binders of the pillow blocks are not screwed up, and that the journals sit fairly on the brass. The above-cited cases of the speed of beam-engine pistons are all distanced by the extraordinary performance of the 'C. Vanderbilt,' a Sound steamer, in her race, June, 1847. This engine is of 65 in. cylinder and 12 ft. stroke, and on the occasion mentioned, attained to 540 ft., or $22\frac{1}{2}$ double strokes per minute. It is not at all uncommon or extraordinary to obtain a piston speed in beam engines of 400 ft. per minute in this country, but the performance of the 'Golden City,' we think, is the best on record, considering the size of the cylinder.

"Since writing the above, we have ascertained that all the facts just mentioned are below the mark. The 'Mississippi,' a large paddle steamer, having an 81 in. cylinder and 12 ft. stroke, has made 24 revolutions per minute, the wheels having 36 in. dip, and attaining a piston speed of 576 ft. per minute. The 'Metropolis,' a large Sound steamer, having a cylinder of 105 in. diameter and 12 ft. stroke, has made 20 revolutions per minute, and we think a higher number. The working beam on the 'Mississippi' weighs 14 tons; that on the 'Metropolis

about 16 tons. The engine of the 'New World,' a side-wheel steamboat 420 ft. long, on the Hudson river, having a 76 in. cylinder, and 15 ft. stroke, has made 20 revolutions per minute or 50 single strokes. The 'Richard Stockton,' however, has outstripped the whole fleet, and, we think, attained the highest piston speed for an engine of this class ever made in the world. We do not know the exact dimensions of the cylinder, but have been told it is between 50 and 60 in., with 10 ft. stroke. The 'Stockton' has feathering wheels, and makes 32 revolutions, or 64 single strokes per minute; and has done this duty for years, having been built by Robert L. Stevens for the express object of testing the speed at which a piston could safely travel. This is the highest speed within our knowledge ever attained by a piston in an engine of similar size; if any other instances come to mind we shall place them on record. It would be difficult to point out any other class of marine engine of the same size as that in the 'Golden City,' which could achieve $17\frac{1}{2}$ turns a minute, and keep it up as a regular duty. The standard of 250 ft. per minute will have to be changed, and made to suit modern pistons, as the engines themselves stubbornly refused to be controlled by any such snail-like movement."

Beam-engines at best are massive and expensive forms of steam motors, and even taking into consideration their economy; yet when first cost, expense of foundations, supplying water for injection, and other accessories of such an engine are considered, we doubt whether this economy will prove so prominently high. The most advantageous application of the beam-engine is that used for pumping. Few engines, of whatever form, have been able to compete with the Cornish beam-engines in obtaining a similarly useful effect produced from a given quantity of fuel.

The beams of such engines now under consideration have hitherto been made of cast-iron; but the melancholy accident at the "Hartley pit" has had a most decided tendency to convince engineers of the importance of placing little confidence in the treacherous nature of cast-iron for such purposes, and of adopting in its place wrought-iron plate beams, which are in every respect superior. Of this dreadful accident, the following is an extract from a practical investigation of the cause of

such a disastrous occurrence from the "*Practical Mechanics' Journal*:"—

"At Newcastle, at the exhibition of objects of scientific or other interest or novelty, produced at the Central Exchange during the British Association's meeting—an exhibition whose character we may say in passing was highly creditable to Northumberland in every way—a model was shown by Messrs. Joicey and Co. (374), of a malleable iron beam for colliery pumping engines. It was a well-devised box girder beam, consisting of two vertical sides bounded by elliptical curves at top and bottom, and connected by a flat web plate all round, divided by diaphragms at various points, and provided with the requisite bosses, &c., for the several gudgeons or axes of the beam and of the parts of the engine. The joints, &c., being all double lapped and double riveted. No doubt, as good a structure probably as could be put together of boiler plate, so far as could be judged from a model only to a small scale; but we submit that this does not decide the question whether wrought iron, in any form, be upon the whole preferable to cast iron, *applied in the best manner*, for such engine beams; and if so, whether boiler plate work in any form be the best possible mode of applying wrought iron, whether it may not have itself, however convenient and cheap in formation, some special disadvantages; whether some far better form of wrought-iron work might not be conceivable; and finally, whether some material, such as steel, might not be superior to both cast and wrought iron.

"We may not be able to enter upon all these points, and indeed might not be able to settle them; but preliminary to all other questions of the sort, it has always appeared to us that it ought to have been settled in the most scientific, positive, and *demonstrative* manner, how, and in precisely what way the Hartley beam (that originated by its fracture this proposed change of material) gave way—that is to say, that it was all-important to have discovered at the time of that accident, by the clearest chain of circumstantial evidence available, *how the fracture occurred*, and to have sealed the truth of the conclusion come to, as to the immediate cause, by *demonstrating, upon rigid principles, that the motions and forces so concluded upon, were sufficient to have produced the effect attributed to them.*

"This, it appears to us, has never yet been done. The evidence given at the coroner's inquest had the usual amount of looseness and inconclusiveness, and at any rate, throughout it (as reported) no attempt to demonstrate, upon mechanical principles, the precise train of forces that caused the fracture, is to be found.

"The official report made to Sir George Grey, Secretary of State for the Home Department, by Mr. J. Kenyon Blackwell, one of the Government Inspectors of Mines—a clear and able document upon the whole—*suggests*, rather than affirms, the train of causation that resulted in the fracture; but the author does not commit himself even to a clearly dogmatic affirmation of the cause, and makes no attempt whatever to demonstrate, on mechanical principles, whether what he suggests as having led to the catastrophe, was *adequate* to produce the results he is to be understood as having attributed to it.

"This report of Mr. Blackwell's is, however, the most precise and authentic document, we presume, before the world on the subject of the Hartley beam breakage; and in view of a case so grave as this, one in which 204 persons perished as a consequence, it certainly does not reflect much credit upon British science, that an event so full of peril and agony of heart to many, and from which such lessons as should effectually avert a recurrence ought to have been educed, has been suffered to pass by unimproved, beyond what may be extracted from the merely suggested and undemonstrated conclusion of the report we have referred to.

"Let us very briefly refer to the facts. The engine beam which broke was a double-flitched beam of cast iron of the form shown in figs. 1 and 2. It was 34.5 ft. long from centre to centre of

Fig. 1.

Fig. 2.



the end gudgeons; it was 8 ft. deep at the centre (according to Mr. Blackwell's report), 8 ft. 2 in. as stated by Mr. Short at the inquest, and 8 ft. 7 in. as given and figured in a contemporary and usually well-informed journal. In this singular discrepancy upon so important a point, we must accept the first as the only authentic statement. Each flitch was 4.75 in. in thickness, exclusive of the metal of the ribs and boss. They were pierced with an hexagonal eye, for the centre gudgeon, the diameter from side to side of the hexagon being 1.75 ft., and this centre of motion was 8 in. nearer to the end of the beam over the pit, than to the other at which the steam cylinder was placed.

"The centre gudgeon was keyed in by large rectangular keys, driven (in pairs on each flat of the hexagon) by the sledge or tup, and with great force. The engine was a double-acting one, *i.e.*, it condensed at both sides of the piston; its stroke was 10 ft., cylinder 86.5 in. diameter, steam in boiler 14 lbs. pressure. It had at a previous period worked at $4\frac{1}{2}$ strokes per minute, but at the time of the accident was working $7\frac{1}{2}$ strokes per minute. We must presume it to have been regulated by a cataract, as we cannot suppose continuous work at the velocity of 90 ft. a minute, or even of 150 ft.; and, if so regulated, the velocity of making the stroke will have been nearly the same in either case, and then, the following passage in Mr. Blackwell's report is difficult to comprehend:—'That liability to breakage existed in this engine was proved by a former accident which occurred in 1858, when its *speed* was only $4\frac{1}{2}$ strokes per minute, instead of $7\frac{1}{2}$ strokes, as at the period of this accident.'

"The engine worked three sets of pumps—two, one lower and one upper, in the pit shaft, both bucket pumps, of 2 ft. diameter working barrel, by 9 ft. 3 in. stroke. The dry spears were of Memel timber, from 14 in. to 10 in. square. The bottom set lifted the water 52 yards, to the other, which raised it 66 yards to the high main seam.

"The third set of pumps were situated at the engine cylinder end in 'a staple.' They were bucket pumps also, 2 ft. 6 in. working barrel, 6 ft. 3 in. stroke, worked from the engine beam between the cylinder and beam centres. There was a counter beam and balance weight shackled on to the engine cross-head above the cylinder, to balance the whole system, as shown in the

lithographs published at the time by Lambert, of Newcastle. This is also distinctly stated by Mr. Short, the engineer of the colliery, at the inquest—‘the load of the engine is balanced by a counter beam.’ (*Times*, Feb. 6, 1862). But Mr. Blackwell does not mention this, and says the balance was produced by ‘the smaller weight of the top set in the staple, which was connected with the engine beam on the opposite side of its centre of motion to the bottom and middle sets, was compensated by the difference in length of the two ends of the engine beam from the centre of motion—the weight of the steam piston, the piston rod, cross-head, and iron catch-pin attached to the beam.’

“The pressure on the steam piston, by steam and vacuum, Mr. Blackwell says, was about 62 tons. The weight of the wet and dry spears, buckets, and columns of water in the two sets of pumps in the pit shaft (at the outer end of the beam) when the engine was about to make a stroke indoors, he states was about 55 tons. Mr. Short, the engineer of the colliery, stated at the inquest, that the weight of the engine beam itself was 42 tons, and ‘the total weight on the beam working both in and out,’ between 107 and 108 tons. He also stated, ‘the weight it had to lift, including the spears and the column of water, was 43 tons 18 cwt., and that the united weight of the engine piston and rod, and cross-head, was 11,536 lbs.—rather more than 5 tons’ (*Times*, Feb. 6, 1862).

“There is a good deal of discrepancy here between parties, both of whom must be deemed authorities. It would appear, however, that the active load upon the beam was something between 108 and 117 tons, and that its passive load was its own weight and those of its attached appendages in addition.

“The beam had been cast at the Walker Ironworks, and Mr. Warrence deposed that it was composed of $\frac{1}{3}$ Blaenavon No. 3 cold blast iron, mixed with $\frac{2}{3}$ No. 1 O.M.O. Scotch pig. It was also proved, we believe, to have been flaked, and not cast in open sand, as stated by Mr. Hoskings, C.E., at the inquest. The cast iron was examined at the School of Mines, Jermyn-street, and we are indebted to Dr. Percy for the following determination made of the amount of injurious constituents present in 100 parts of iron, and carbon, &c.

Phosphorus	.	.	.	.	1.11
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Silicon	2.68
Sulphur	0.16

"The iron, therefore, was by no means bad in quality. The beam suddenly broke right through the eye, the fracture running in the direction marked in the fig. by a dotted line, and passing through the two diagonally opposite, sharp re-entering angles of the hexagonal eye—in this, as in every other case, showing that the fracture chooses not the very weakest *measured section*, which here would have been right across the beam, but the weakest place, section and quality of material taken together. Here through these angles, where 'planes of weakness' were induced by the peculiar crystalline arrangement induced by the sharp angles of the eye.

"The fracture showed no old crack, it was bright all over; adherent shreds of torn out iron were remarked upon by one witness as a proof of the toughness of the metal; but no observation appears to have been made by any one with a view to determine which was the compressed and which the extended side of the beam at the time of fracture; whether by the position of these shreds above or below the axis, or otherwise; a most singular omission, when we bear in mind that the point most important to be determined in the first instance was, whether the beam broke by a force acting from below upwards at one end, or by one acting in the reverse direction, *i.e.*, whether by a concussion after the pump spears broke, or by a dead pull suddenly arrested. The fracture also showed four great 'draws' or hollows left by the shrinkage of the metal as it consolidated. These were at the sides of the central bosses, where the solidifying iron remained last liquid in the mould.

"The pump spears in the pit shaft were both found broken. Mr. Coulson, the veteran master sinker of eighty-four coal-pits, and whose voluntary and unremunerated exertions to relieve the buried men, along with those of his son and foreman, have made their names justly renowned, deposed that the fracture was about 14 fathoms from bank, in the main spears, and opposite the middle seam, *i.e.*, about 60 yards lower in the other spears; both he and Mr. Short appear to intimate that the fracture of the timber indicated a *pull asunder end on*, and not a cross fracture.

"There appears some discrepancy also as to the quality of the timber, some of the witnesses at the inquest stating that at the fracture it was perfectly sound, an opinion that from personal communication we are aware is Mr. Coulson's also. Mr. Blackwell, however, states 'the wood in the bottom dry spear near the place where it parted was found to be not perfectly sound.'

"The engine piston, &c., had completed a down stroke after the beam had broken, the cylinder end of the beam had come down heavily upon the catches and spring beams, and the cross-head or piston cap had been fractured. The pumps in 'the staple' had nothing wrong with them.

"The outer end of the engine beam, on breaking off, plunged down the pit shaft, carrying the wooden brattice (which ran east and west, while the length way of the beam was north and south) crashing down into the shaft before it, and blocking up the latter with debris from the shaft lining, and the ruin of the pit work generally, at about 138 yards from the bank, where all were arrested by the oak buntons on which the middle set of pumps rested. With these details, or with the terrible circumstances of the imprisonment of the men and the heroic efforts made to release them, continued for long after they had been released from all bodily suffering by the easy death of suffocation by 'the stythe,' we have nothing here to do.

"What we propose to consider, by the help of mechanics, how far confidence may be placed in either of the solutions that have been given of the precise train of forces that produced the accident, and then to draw some practical conclusions, amongst others, as to the comparative advantages and disadvantages of wrought-iron or other beams, as substitutes for cast-iron. For the mathematical treatment of the question, we are indebted to our distinguished friend and contributor Professor Samuel Haughton, Professor of Geology, and Fellow of Trinity College, Dublin."

"The problem itself is a dynamic question of considerable complexity, as is pretty evident from the fact that, so far as our knowledge goes, not one of the many able colliery engineers of the North, no one, indeed, has ever attempted to grapple with it, up to this date, when the accident itself is almost beginning to be forgotten.

But first let us set aside one or two of the popular views on the subject, as amongst those that, it may be pronounced with certainty, *could not possibly* account for the fracture. First, it cannot have broken simply by statical overloading, long continued. A writer in *The Engineer* (Feb. 28, 1862) calculates the statical strength of the beam from the common formula—

$$\frac{(BD^2 - bd^2) 0.25 S \times 4.5}{L} = W.$$

the breaking weight, and upon the data following—

B = 8 inches; D = 98 inches, the full length of the line of fracture;

b = 3.25 inches; d = 86 inches; and

L = 18 feet; S = 296 lbs. for a bar of cast-iron 1 inch square;

and arrives at the conclusion that the ultimate breaking weight of the beam was = 976,707½ lbs., or about 436 tons; and calculating the greatest dead load upon the beam at 64,641½ lbs., or under 29 tons, and deducting 10 per cent. from the first value of W for defective casting (*i. e.*, the draw holes at the bosses), he points out that the statical load was no more than $\frac{1}{13.5}$ of the breaking strain.

This is the smallest estimate that we have seen made in figures, of the passive strength of the beam, and it undoubtedly underrated both the breaking weight and the load.

A more trustworthy calculation was given by Mr. Atkinson, Government Inspector of Mines, in vol. 11 of the 'Transactions of the Northern Mining Institute.'

From the formula—

$$\frac{500 \times BD^2}{L} = W.$$

and upon the data that the statical breaking weight of a bar of sound cast-iron 1 inch square, and 1 foot long, *encastré* at one end, and loaded at the other, is = 506 lbs. reduced to 500, as the beam was unsound at the bosses; and taking *mean* values for B and D, the line of fracture being 8 feet 2 inches deep, he calculates the value of

	Tons.	Cwt.	Qrs.	Lbs.
W =	1413	8	3	18

But the statical load, or 'greatest steady strain,' he says, did not exceed 106 tons 8 cwt. 3 qrs. 1 lb., acting at 18 feet from the

line of fracture, from which it follows that the greatest load was only about $\frac{1}{13.25}$ the ultimate strength. The two ratios, though on independent and different data, closely coincide.

Now, as it is perfectly well known that, even under impulsive strains, cast-iron may be exposed to forces producing more than one-fifth its ultimate extension, and remain for decades of years uninjured, there can be no hesitation in pronouncing that it is physically impossible that the Hartley beam was broken by the long-continued action of its steady load, even making every estimate of allowance for the variable nature and alternation of that load.

In what follows, we shall find that Professor Haughton has examined the question arising out of one of the other suppositions as to cause, namely, the possible strain that might have been visited upon the beam by the fall it got from off the screw-jacks.

That view alone *looked* feasible, because it was beyond the reach of the judgment we form by tactile experience of such things; no one could, by any analogy of experience, imagine what might be the stress upon such a mass of 42 tons, dropping upon two points at its mid length, from even a few inches in height.

Let us come, then, to what we may call the authorized version of the conditions that produced fracture. After describing the engine, the beam, and the loads which he calculated were upon it, Mr. Blackwell states—‘It appeared from the evidence of the men being wound up in the shaft at the time of the accident, that *a breakage of the spears in the shaft, by which the engine lost its load wholly or in part*, did occur prior to the breakage of the beam and the fall of its broken half into the pit;’ ‘and that when this breakage of the spears did occur, the engine was commencing its inside stroke.’

He proceeds—‘The resistance to the descent of the piston in the steam cylinder being thus removed, the piston would be carried downwards by the pressure of the steam on its upper surface, augmented by the vacuum below, amounting to a force of about 62 tons, and would rapidly acquire momentum in its descent through a stroke of 10 feet in length, until both the piston and that end of the beam connected to it were suddenly arrested by *the iron catch-pin, fixed upon the beam at that point, coming*

down upon the spring beams, where they were rendered perfectly rigid in their resistance by vertical cast-iron columns beneath them.'

'The engine beam was of iron of *fair quality*.' 'It was of the full ordinary sectional dimensions of beams used in engines of similar power.' 'The over-wedging of the beam centre *may have contributed* to render it *more liable* to fracture,' but is 'not alone sufficient to account for the fracture.'

'*The breakage of the beam must be attributed to the violent concussion to which it was subjected*, when it, together with the steam piston connected to it, were suddenly arrested, after descending through a stroke of 10 feet, with the velocity acquired under the pressure of the steam, by coming in contact with the spring beams beneath, after the counterbalancing load in the shaft was partially or wholly lost.'

"Such, in clear language, is Mr. Blackwell's decision. We shall, without further preface, submit it to the calculus of Professor Haughton. In the present section of these 'notes,' we cannot do more than give the preliminary investigation made by that gentleman, upon data supplied by us, and not rigidly exact, and which he desires shall be received as no more than a first approximation to the problem of the Hartley beam. Upon more precise data, as to loads and dimensions, form of the beam itself, etc., since then obtained, Dr. Haughton is still engaged with the calculation, and we hope in a succeeding part to give fully his exact determination of the strain possible to be produced by the train of circumstances set forth by Mr. Blackwell. Meanwhile the following calculations will show the methods employed, and indicate the probable result of the final investigation."

APPROXIMATE SOLUTION OF QUESTIONS RELATIVE TO THE FRACTURE OF THE HARTLEY BEAM, BY REV. SAMUEL HAUGHTON, F.T.C.D., F.R.S.

PROP. I.—PROBLEM.

A beam, of rhomboidal shape, is supported by an axis passing through its centre, and loaded with equal weights at its extremities; it is required to find the tension and compression to which its parts are exposed.

Let l denote half the total length of the beam,
 Let d , its depth,
 Let t , its thickness;
 Let W denote the weight of the beam,
 and P , the weight suspended at each extremity.
 The *Moment of rupture* of the beam is equal to

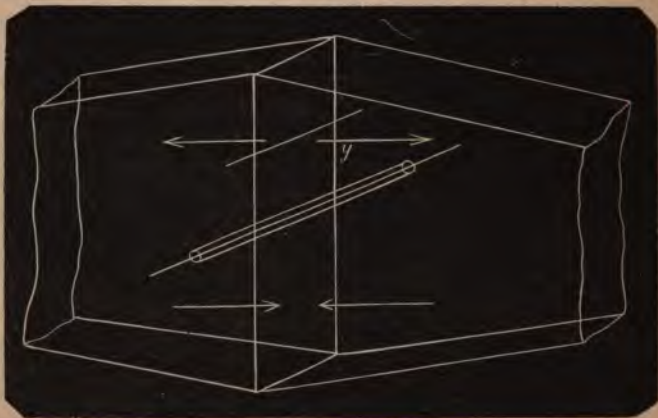
$$\frac{(W + 6 P) l}{6};$$

and the *Moment of resistance to rupture* is

$$t \int Fy \, dy;$$

where F denotes the tension or compression per sq. in. at any distance, y , from the axis of the beam, in its central vertical section (fig. 3). If C denote the tension or compression per sq.

Fig. 3.



in. at the top or bottom of this section, then, (assuming for the present that the *neutral axis* passes through the centre of the beam,) we have, by Leibnitz' principle,

$$F = C \frac{2 y}{d}$$

therefore, equating the moments of rupture and resistance, we have

$$\frac{(W + 6 P) l}{6} = \frac{2 t C}{d} \int y^2 dy = \frac{2 t C}{d} \cdot \frac{y^3}{3} + \text{Const.} \quad (1)$$

This integral must be taken for the extended portion of the section, from $y = +\frac{d}{2}$ to $y = 0$; and for the compressed portion from $y = -\frac{d}{2}$ to $y = 0$; or, since both extension and compression are employed in resisting rupture, from $y = +\frac{d}{2}$ to $y = -\frac{d}{2}$; therefore

$$\frac{(W + 6 P) l}{6} = \frac{C S d}{6}$$

or

$$(W + 6 P) l = C S d \quad (2)$$

where $S = t d$ = the cross sectional area of the central vertical section of the beam.

Therefore, finally,

$$C = \frac{(W + 6 P) l}{S d} \quad (3)$$

Example 1. If the beam be 34 feet long, 8 feet deep, and $9\frac{1}{2}$ inches thick, weighing 42 tons, and be loaded with 300 tons at each end, find the strain on each square inch of the top of the vertical central section—

$$C = \frac{(42 + 1800) 17}{912 \times 8} = 4.292 \text{ tons per sq. in.}$$

Example 2. If the beam be unloaded, find the strain per sq. in.—

$$C = \frac{42 \times 17}{912 \times 8} = \frac{1}{10.2} \text{th of a ton per sq. in.}$$

Example 3. If the maximum strain that cast-iron will bear, if suddenly applied, be 2 tons per sq. in., calculate the forces, P , suddenly applied downwards to the extremities of the beam that will just fracture its upper surface in the central section.

In equation (2), write $C = 2$, and solve for P .

$$\begin{aligned}(42 + 6 P) 17 &= 2 \times 912 \times 8 \\ 714 + 102 P &= 14592 \\ P &= \underline{\underline{136 \text{ tons.}}}\end{aligned}$$

PROP. II.—PROBLEM.

If an unloaded rhomboidal beam fall on its bearings through a height, h , find the coefficient of strain per sq. in. on the upper portion of the central section.

The momentum of each half of the beam, acquired in falling through the height, h , is, (if V . be the velocity acquired),

$$\frac{W}{2} \times \frac{V}{g};$$

the moment of which, with respect to the axis, must be equated to the moment of resistance to rupture; therefore

$$\frac{W V l}{6 g} = \frac{C S d}{6};$$

or

$$\frac{W V l}{g} = C S d;$$

or

$$C = \frac{W V}{g S d}. \quad (4)$$

But, since $V = \sqrt{2 g h}$, this equation becomes

$$C = \frac{W l}{S d} \sqrt{\frac{2 h}{g}} \quad (5)$$

The quantity $\sqrt{\frac{2 h}{g}}$ denoting the time of falling through h .

Example. If the dimensions of the beam be the same as before, find the strain produced by falling through 4 inches. Here, g must be expressed in inches, and is equal to 386 inches; therefore

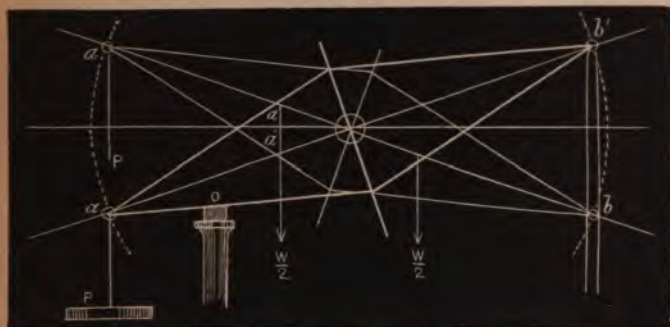
$$\begin{aligned}C &= \frac{42 \times 17 \times \sqrt{8}}{912 \times 8 + \sqrt{386}} \\ &= \frac{21 \times 17}{456 \times \sqrt{3088}} = \frac{1}{71} \text{ st of a ton per sq. in.}\end{aligned}$$

PROP. III.—PROBLEM.

"A rhomboidal beam, lifting pump spears at one end, and worked by the cylinder of a steam engine at the other end, at the commencement of a stroke is suddenly strained by an obstacle catching the spears, which are broken across, when the released beam is drawn down by the piston of the engine, and its motion is suddenly stopped by a spring beam (supposed to coincide in position with the centre of percussion of the beam): find the strain per sq. in. on the lower portion of the central section of the beam."

Let $a\ b$, (fig. 4), denote the position of the beam when the

Fig. 4.



spears are broken, and $a'\ b'$ its position when its motion is suddenly destroyed by the spring beam, O , and let α and α' be the angles made above and below the horizontal line by the centre line of the beam in these two positions, θ denoting the angle, made in any position of the beam, with the horizon.

Then, if ω be the angular velocity of the beam, by well known Mechanical principles, we have

$$\frac{d\omega}{dt} = \frac{\text{Statical Moment}}{\text{Moment of Inertia}} = \frac{P\ l\ \cos \theta}{I};$$

P denoting the force of the piston drawing down the beam, and I its *moment of inertia*, including this force.

The equation just written, since $\omega = \frac{d\theta}{dt}$, is

$$\frac{d^2\theta}{dt^2} = \frac{P l \cos \theta}{I}$$

multiplying both sides by $\frac{2 d\theta}{dt}$, we find

$$\frac{2 d\theta}{dt} \frac{d^2\theta}{dt^2} = \frac{2 P l}{I} \cos \theta \frac{d\theta}{dt};$$

which, by integration between the limits $\theta = +\alpha$, and $\theta = -\alpha'$ becomes

$$\left(\frac{d\theta}{dt}\right)^2 = \omega^2 = \frac{2 P l}{I} (\sin \alpha + \sin \alpha').$$

And, if $h = l \sin \alpha + l \sin \alpha'$, be the total vertical height through which the end of the beam descends before it strikes the spring beam—

$$\omega^2 = \frac{2 P h}{I};$$

or

$$\omega I = \sqrt{2 P h I}. \quad (6)$$

Now, it is well known that the quantity of work stored up in a body revolving round an axis, is equal to the quantity of work stored up in one moving in a right line, with the velocity of the centre of gyration, and having a mass equal to that of the whole body revolving; or,

The Moment of Rupture stored up in the beam = ωI ;

and, since the engine beam strikes the spring beam in the centre of percussion, the whole work stored up in the beam will be spent in fracturing it, and none spent in a shock at the axle; therefore, as we have before found the moment of Resistance to rupture to be $\frac{C S d}{6}$, we have

$$\omega I = \sqrt{2 P h I} = \frac{C S d}{6}$$

and, since $I = \frac{(P + W) R^2}{g}$; R being the radius of gyration, we obtain, finally

$$C = \frac{6 R}{S d} \sqrt{\frac{2 P (P + W) h}{g}} \quad (7)$$

If α and β be the diagonals of a rhombus, its radius of gyration, with respect to an axis, passing through their intersections, and perpendicular to the plane of the rhombus, can be proved to be

$$R^2 = \frac{\alpha^2 + \beta^2}{6}; \quad (8)$$

which becomes, in the case of the engine beam,

$$R^2 = \frac{d^2 + 4 l^2}{6}$$

therefore, since

$$(P + W) R^2 = W R^2 + P l^2;$$

equation (7) may be thus written, taking account of the weight, P,

$$C = \frac{6}{8 d} \sqrt{\frac{P h [W (d^2 + 4 l^2) + 6 P l^2]}{3 g}} \quad (9)$$

Example 1. Let P be 100 tons, and h equal to 8 ft. Find the strain C.

$$\begin{aligned} \text{Since} \quad R^2 &= \frac{W (d^2 + 4 l^2) + 6 P l^2}{6 (P + W)} \\ &= \frac{42 (64 + 1156) + 173400}{6 \times 142} = 263.66 \end{aligned}$$

and, therefore, $R = 16.2$ ft.

Using this value of R, in equation (7), we find

$$\begin{aligned} C &= \frac{6 \times 16.2}{912 \times 8} \sqrt{\frac{100 \times 142 \times 8}{16}} \\ &= \frac{81}{6080} \sqrt{7100} = 1.123 \text{ tons per sq. in.} \end{aligned}$$

In the preceding example, the beam of the engine is supposed loaded with a weight or force, P, at one end, and to carry no load at the other. If we suppose a load at each end of the beam P and P¹, the equation (7) must be changed into the following—

$$C = \frac{6 R}{8 d} \sqrt{\frac{2 (P - P^1) (P + P^1 + W) h}{g}}; \quad (7) \text{ bis.}$$

in which R is determined by the equation

$$(P + P^1) l^2 + W R^2 = (P + P^1 + W) R^2 \quad (10)$$

Example 2. Let P be 62 tons, and P^1 be 20 tons, everything else remaining as before; then from equation (10) we find

$$\begin{aligned} 124 R^2 &= 32238 \\ R &= 16.1 \text{ feet.} \end{aligned}$$

Hence,

$$\begin{aligned} C &= \frac{6 \times 16.1}{912 \times 8} \sqrt{\frac{42 \times 124 \times 8}{16}} \\ &= \frac{161}{12160} \sqrt{2604} = 0.675 \text{ of a ton per sq. in.} \end{aligned}$$

The preceding results are to be regarded as only a first approximation to the exact discussion of the important problem of the Hartley Engine Beam, which will require, for its solution, to have taken into account the elliptical shape and eccentricity of the beam, and the weights of the piston and condensing pumps, and the top lift of pumps in the staple, as well as the steam pressure, and weight of the bottom and middle lifts and water.

In the preceding part of his investigation, Professor Haughton considered roughly, in Prop. III., the conditions of rupture of an engine beam, suddenly stopped by a spring beam, regarded as an immovable obstacle, and supposed to be placed at the centre of percussion of half the loaded beam. He desires here to correct an error that has been printed in his solution.*

It is known, and will be proved in the following pages, that the whole of the work stored up in the half beam that strikes the spring beam is destroyed by the shock, and passes into the spring beam, in consequence of the latter being placed at the centre of percussion of the half beam. Hence, in estimating the moment of rupture (ωI), the inertia of the other half only of the beam should have been computed. By some inadvertence in the calculation, ωI has been computed for the whole beam, instead of the half beam. The correction of this error will reduce the numerical values deduced from Prop. III. to half their amount, so that the insufficiency of the shock to break the beam may be regarded as fully proved, if we accept the principle of

* We take the blame of this quite upon ourselves. The MS. was not returned to be examined by us with the proofs, and through failure of time before going to press, no proofs were forwarded to Professor Haughton, and so the error was not discovered prior to publication; it is one that does not affect the method employed in any way.—*Ed. Pract. Mechs. Journal.*

equating the dynamical moment of rupture to the static moment of resistance.

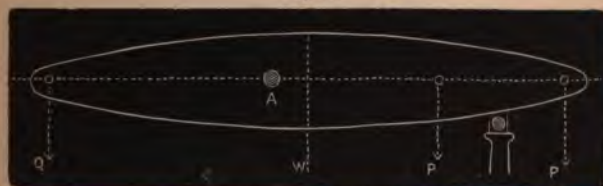
But this principle, however usual, is in itself very unsatisfactory, because it requires us to compare a *momentum* with a *weight*, and mechanicians are not yet agreed upon the conditions and restrictions within which such a comparison can be regarded as true to nature. Professor Haughton considers, however, that the method he finally employs in solving the problem of the Hartley beam is based on principles against which no such theoretical objection can be raised. The method of solution of the problem is contained in the following Propositions:—

- A. There is first found the work stored up in the beam at the instant of striking the spring beam.
- B. The work left in the beam, after striking the spring beam, is then determined.
- C. The work of resistance of the cross section of the beam, due to the extension and compression of its parts, is also found, and there is then instituted—
- D. A comparison of the work left in the beam after the shock on the spring beam, (B), with the work of resistance, (C).

PROP. A. *To find the work stored up in the Hartley beam at the moment of striking the spring beam.*

The Hartley colliery beam may be regarded as an ellipse, whose centre of motion, A, fig. 5, of the subjoined engravings, is

Fig. 5.



9 inches nearer to the outer end, (Q), than its centre of figure is placed; and it is acted on by the following forces. P. the steam pressure on the piston plus the weight of piston rod, etc.;

P' , the weight of the dry rods in the pumps of the top staple; w , the weight of the unloaded beam; Q , the weight of the broken spears of the pumps of the lower and middle lifts. The beam, acted on by all these forces, moves from rest until, the force P , having passed through 10 ft., the whole system impinges upon the spring beam, B . It is required to find the work stored up in the beam. Let a, b , denote the semi-axes of the beam, and let p, p', w, q , denote the distances of the points of application of the forces, P, P', W, Q , from the axis of motion, (A): if h denote the height through which the force, P , descends, then the

$$\text{Work stored up in the beam} = (Pp + P'p' + Ww - Qq) \times \frac{h}{p} \quad (1.)$$

Assuming as the data furnished—

$P = 70$ tons	$= 62 + 8$		$p = 18$	ft.
$P' = 8$	„		$p' = 11$	„
$W = 42$	„		$w = 3\frac{3}{4}$	„
$Q = 12$	„		$q = 16\frac{1}{2}$	„
			$h = 10$	„

we have

$$\begin{aligned} Pp &= 1260 \text{ ft. tons.} \\ P'p' &= 80 \text{ „} \\ Ww &= 31\frac{1}{4} \text{ „} \\ Qq &= 198 \text{ „} \end{aligned}$$

Substituting these values in equation (1), we find the

$$\left. \begin{array}{l} \text{Work stored up in the Hartley beam} \\ \text{at the moment of the shock,.....} \end{array} \right\} = \frac{1181.5 \times 5}{9} = 656.4 \text{ ft. tons.}$$

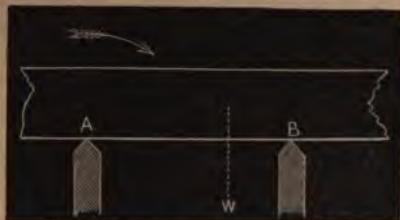
PROP. B. *To find how much of the work stored up in the beam at the moment of the shock, remained in it after the shock.*

To solve this problem, Professor Haughton discusses the following lemma:—

A beam, turning with an angular velocity (ω) round a point (A), fig. 6, falls upon the point, B ; it is required to find the angular velocity (ω') with which it commences to revolve round (B).

Let a denote the horizontal distance of the centre of gravity of the beam from the point A , and let f denote the distance of B from A . The blow with which B strikes the beam may be represented by mv , where m denotes the mass of the beam, and v a certain velocity to be found.

Fig. 6.



It follows, from the well-known principle of D'Alembert, that

$$m v f = \omega I \quad (2.)$$

and that the shock on the beam at the axis (A) is

$$= m (v - \omega a) \quad (3.)$$

In consequence of this shock, the beam commences to turn round the point, (B), with an angular velocity determined by the equation

$$m (v - \omega a) f = \omega' I' \quad (4.)$$

In these equations, I and I' denote the moments of inertia of the beam, with respect to the points, A and B. Substituting the value of c found from (2) in equation (4), we find, after some reductions—

$$\omega' I' = m \omega (k^2 - a f) \quad (5.)$$

where k is the radius of gyration corresponding to the point A, or

$$I = m k^2;$$

if k' denote the corresponding radius of gyration for the point B

$$I' = m k'^2$$

and substituting in (5), we obtain finally

$$\omega' = \omega \frac{k^2 - a f}{k'^2} \quad (6.)$$

which is the angular velocity with which the beam commences to revolve round B.

Now, to deduce from this lemma the quantity of work remaining in the beam after the shock, Professor Haughton makes use of the following well-known principle, also employed in the previous part of this investigation, viz.,

The work stored up in a revolving body is equal to the work stored up in a body of the same weight moving in a right line, with a velocity equal to that of the centre of gyration.

Hence, the work remaining in the beam is

$$\frac{\omega'^2 k'^2}{2g} \times \text{its weight.}$$

Substituting in this expression for ω'^2 , its value deduced from (6) we find

$$\text{Work left in the beam} = \frac{\omega^2}{2g} \times \frac{(k^2 - af)^2}{k'^2} \times \text{its weight,}$$

and since, by the same principle, the original work stored up in the beam was

$$\frac{\omega^2 k^2}{2g} \times \text{its weight,}$$

we find at length

$$\text{Work left in the beam} = \frac{(k^2 - af)^2}{k^2 k'^2} \times \text{work stored up originally.} \quad (7.)$$

In order to apply this result to the Hartley beam, it is necessary to calculate k , k' , and a , and to know the line f , or horizontal distance of the centre of motion from the spring beam.

The square of the radius of gyration, k^2 , is found from the following equation:—

$$(P + P' + W + Q) k^2 = Pp^2 + P'p'^2 + W(w^2 + \rho^2) + Qq^2 \quad (8.)$$

in which ρ denotes the radius of gyration of the unloaded beam round its centre of figure or gravity. The other quantities have been already given, and ρ is known from the expression for the radius of gyration of an ellipse, with respect to an axis passing through its centre, and perpendicular to its plane.

$$\rho^2 = \frac{a^2 + C^2}{4} *$$

or

$$\rho^2 = \frac{(18\frac{1}{2})^2 + 4^2}{4} = \frac{356.25}{4}$$

and adding

$$w^2 = \left(\frac{3}{4}\right)^2 = \frac{2.25}{4}$$

* *Whewell's Dynamics*, Part II., p. 228. Cambridge, 1834.

we obtain

$$r^2 + w^2 = \frac{359.5}{4} = 90 \text{ qu. pr.}$$

Hence, we find

$$\left. \begin{array}{l} Pp^2 = 22680 \\ P'p'^2 = 1056 \\ W(r^2 + u^2) = 3780 \\ Qq^2 = 3267 \end{array} \right\} = 30,783$$

but $P + P' + W + Q = 132$ tons, and therefore equation (8) gives

$$k^2 = \frac{30783}{132} = 233.2$$

In order to find k'^2 , we must use equation (8), substituting for p, p', w , and q , the distances of the spring beam from P, P' , the centre of the beam, and Q . Hence, since $f = 15$ ft., the right hand side of (8) becomes,

$$\left. \begin{array}{l} (P) \ 70 \times 3^2 = 630 \\ (P') \ 8 \times 4^2 = 128 \\ (W) \ 42 \times \left(\frac{356.25}{4} + (14\frac{1}{4})^2 \right) = 42 \times 292 = 12264 \\ (Q) \ 12 \times (31\frac{1}{4})^2 = 11907 \end{array} \right\} = 24929$$

Hence, from (8) we find

$$k'^2 = \frac{24929}{132} = 188.8$$

The distance of the centre of gravity from the centre of motion is found by the equation

$$(P + P' + W + Q) a = Pp + P'p' + Ww - Qq \quad (9.)$$

or

$$132 a = \left\{ \begin{array}{l} + 1260 \\ + 88 \\ + 31\frac{1}{4} \\ - 198 \end{array} \right\} = 1182 \text{ qu. pr.}$$

or

$$a = \frac{1182}{132} = 9 \text{ ft. qu. pr.}$$

Substituting the preceding values in equation (7), we find

$$k^2 - a f = 233.2 - 9 \times 15 = 98.2$$

and finally

$$\text{Work left in the beam after the shock, ...} = \frac{(98.2)^2 \times 656.4 \text{ ft. tons}}{233.2 \times 188.8} = 143.77 \text{ ft. tons.}$$

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PROP. C. To find the work of resistance of the Hartley colliery beam due to the extension and compression of its parts.

Let A B, fig. 7, denote the position of the neutral axis of the beam $a b$, and let c c' denote the coefficients of extension and compression at the points b and a , when the beam is on the point of breaking. If y be the distance of any element from the axis, we have

$$\frac{C}{b} \int_0^b y \, dy = \frac{C'}{b'} \int_0^{b'} y \, dy; \quad (10.)$$

an equation which expresses the fact that the sum of the forces of extension is equal to that of the forces of compression. Hence

$$C b = C' b' \quad (11.)$$

Adopting the experimental results given in the *Report of the Commissioners on Railway Structures*, (1849), p. 101, where it is stated that the ratio of the ultimate compressive and tensile forces deduced from thirty-six experiments on cast iron, is 5.637 : 1, or 17 : 3 *qu. pr.*; Professor Haughton infers from this that the distance of A B from b , is to its distance from a in the same proportion of 17 to 3.

Let dx denote the extension of any element dy of the beam, and let ds be the extension at the point b . The force acting at dy being denoted by F , the work of extension is

$$\text{Work of extension,} = \int F \, dx = \frac{C \, ds}{b^2} \int_0^b y^2 \, dy = \frac{C \, ds \, b}{3}$$

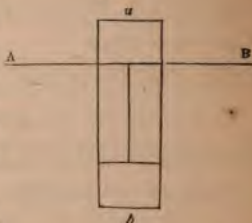
and the work of compression is

$$\text{Work of compression,} = \int F \, dx = \frac{C' \, ds'}{b'^2} \int_0^{b'} y^2 \, dy = \frac{C' \, ds' \, b'}{3}$$

Hence, the total work of resistance, both of extension and compression, is

$$\frac{1}{3} C (ds \, b + C' \, ds' \, b');$$

Fig. 7.



and since

$$b : b' :: ds : ds',$$

it follows from (11) that

$$\text{Work of resistance,} = \frac{C ds}{3} (b + b')$$

or

$$\text{Work of resistance,} = \frac{C ds}{3} \times S; \quad (12.)$$

S denoting the cross section in square inches. It appears from the experiments recorded in the Report already quoted, pp. 51, 52, 53, 55, that the ultimate extensile force of cast-iron is 7.014 tons, and that the extension produced by this ultimate force is $\frac{1}{613}$ th of the length of the bar.

Introducing these values of C and ds into equation (12), and remembering that the Hartley beam was 34 feet long, we obtain

$$\begin{array}{l} \text{Work of resistance of Hartley} \\ \text{steam engine, ...} \end{array} \left. \vphantom{\begin{array}{l} \text{Work of resistance of Hartley} \\ \text{steam engine, ...} \end{array}} \right\} = \frac{7.012 \times 34 \times 912}{3 \times 613} = 118.23 \text{ ft. tons.}$$

PROP. D. *To compare the work left in the beam with the work necessary for fracture.*

The work left in the beam after the shock is employed in deforming the beam into a curve, with a point of contrary flexure, as shown in fig 8, where $n n'$ denotes the neutral axis, and ab a neutral surface, in which there is neither extension nor compression.

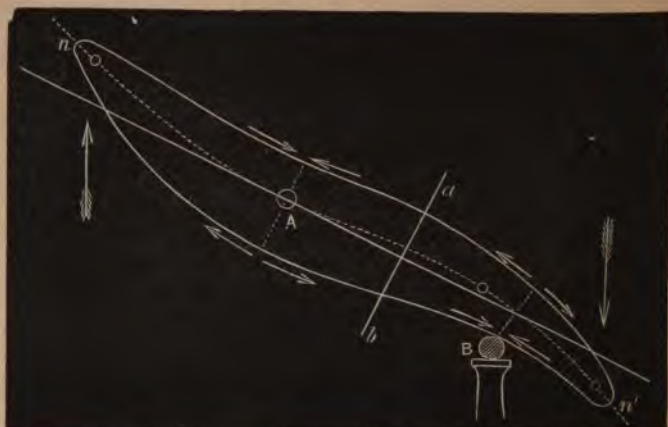
The work expended between n and ab is that with which we are concerned, and the portion expended between ab and n' , is employed in tending to fracture the engine beam on the spring beam, B.

From A to B is 15 ft., and from A to n' is $19\frac{1}{4}$ ft., from which it is probable that by far the greatest portion of the work left in the beam is spent on the portion between ab and n .

The work left in the beam was found to be 143.77 ft. tons, and the work requisite to fracture the beam at A, upon the data given, is only 118.23 ft. tons.

The destructive forces were, therefore, probably in excess of

Fig. 8.



the powers of resistance of the material, even deducting the work expended in tending to fracture the beam at the point B."

The preceding important investigation—which the 'Practical Mechanics' Journal' has done the engineering world good service by publishing—although occupying a considerable portion of our space, will be exceedingly useful to those interested in the designing of such beams, as supplying important mathematical data for ascertaining the precise strains to which such beams are subjected.

Beam steam engines are not the only ones, however, which have "compound" or high and low pressure cylinders, for of late years this system has been much introduced into engines of a horizontal construction, and with the best results. Several cotton factories have had such engines lately put down, some having the high-pressure cylinder immediately behind the low-pressure, the same piston rod passing through both, and the power communicated to one crank. Others have their high and low pressure cylinders lying alongside one another, and the power communicated to cranks set diametrically opposite each other. In both instances the air-pump is wrought from a lever, receiving its motion from the cross-head of the piston.

Another class of horizontal compound engines is that having its high and low pressure cylinders laid, as above, side by side, but the cranks being, instead of diametrically opposite, at right angles. This plan, however, necessitates a receiver to contain the exhaust of the high-pressure cylinder until the low-pressure cylinder has reached the end of its stroke. Messrs. Waller, May, and Co., of Birmingham, exhibited in the late International Exhibition an engine of this description. The receiver or reservoir was of wrought-iron, and jacketed with high-pressure steam from the boiler. Such a plan as this tends to produce a steadier motion in the engine, but beyond this it has no advantages. A still better plan, however, and very much similar to the above, is that of Mr. Wenham, who also exhibited a portable engine having a high and low pressure cylinder, the cranks being placed at right angles. In this case the reservoir was placed in the smoke-box, and consisted simply of a round casing having several tubes coincident with those of the boiler; the exhaust from the high-pressure cylinder was placed in communication with this superheater, and the steam, in passing through it on its way to the low-pressure cylinder, was recharged with a quantity of heat, thus augmenting the pressure of steam, and preventing further condensation consequent upon its increase of volume in the low-pressure cylinder. This we consider the best arrangement of horizontal high and low pressure engine, for it is exactly at this point that the steam, after having been expanded in the high-pressure cylinder, requires to be superheated, and the time is just sufficient to accomplish this—namely, the time occupied between the exhausting of the high-pressure cylinder and the completion of the stroke of the low-pressure cylinder. Such combined high and low pressure horizontal engines are rapidly taking the place of the huge and sluggish beam-engines, with equally good results in economy of fuel, while a saving of 50 per cent. is effected in first cost. Much has of late been argued in favour of the horizontal engine over that of the beam, some recommending high speeds of piston, such as 1,000 feet per minute, and with a high degree of expansion. A very good specimen of such an engine was exhibited in the late International Exhibition, called the "Allan" engine. This engine had a long stroke, and was fitted with a peculiar expansion valve,

whereby the "cut off" was varied by means of a pair of extremely sensitive governors, called the "Porter" governors. This engine was kept running, at a speed of piston equal to 800 feet per minute, with the utmost steadiness, "cutting off" at 10 per cent. of its stroke. We understand the same engine is now at constant work at Messrs. Easton, Amos, and Sons' works, running at a speed of piston equal to 660 feet per minute. Numerous objections are made against *horizontal engines*, but practically they are not very valid. On the subject of comparison of such engines, we extract from the columns of the "Engineer" the following article:—

"There is an unaccountable prejudice on the part of cotton-spinners, corn-millers, and brewers against horizontal steam engines. This prejudice is derived from no experience, for engines of the kind in question have not been put upon anything like a sufficient trial in cotton-mills, corn-mills, or breweries. Nor is the objection founded in reason, for the balance of fact and argument is decidedly against beam engines. They are heavy and costly, require costly foundations, and occupy a great deal of room, and for all this they present no compensating advantages. In respect of weight, which is a tolerable index of cost, we may compare the non-condensing beam engine exhibited last year in the International Exhibition, by Messrs. Mirlees and Tait, with a horizontal engine of the same power, by the same makers, and intended for the same purpose, viz., driving a large sugar mill. The beam engine had a 22 in. cylinder and a 4 ft. 6 in. stroke, while the horizontal engine has a cylinder of the same diameter, with a stroke of 4 ft., making a somewhat greater number of revolutions with the same speed of piston and same total power. In the case of the beam engine, the bed plate weighed 7 tons 14 cwt., the six columns 5 tons 2 cwt., and the entablature 3 tons 5 cwt., making 16 tons 1 cwt. of framing. The bed plate of the horizontal engine weighs 4 tons 13 cwt., or but little more than one-fourth as much, while its actual stability is even then greater than that of the other arrangement of framing. The working beam of the beam engine weighed 2 tons 5 cwt., the whole of which is saved in the horizontal engine. The cylinder of the beam engine being supported upon its end, and *being, also, 6 in. longer*, weighed 17 cwt. more than that of the

horizontal, which, with covers, weighs 1 ton 13 cwt. The 20 ft. fly-wheel of the horizontal engine weighs 9 tons, that of the beam engine, working slower, weighing $13\frac{1}{2}$ tons, although we cannot charge any difference in this respect to the mere arrangement. The whole weight of the beam engine was 44 tons 9 cwt., while that of the horizontal engine is less than 20 tons. The excess of weight fairly attributable to the beam arrangement may be set down as at least 15 tons, and the proportionate cost may be pretty correctly inferred from this difference alone. The difference in the space occupied would be chiefly one of height, which, in this case, would not, perhaps, be of great consequence. With a still larger single cylinder engine, the beam would occupy from 2,000 to 4,000 cubic feet more space than the horizontal. The difference in foundations is also against the beam. The supposed advantages of the beam engine are that the cylinder and piston wear better, and that the parallel motion may be more conveniently applied, and thus economise power supposed to be wasted in friction on the guides of a horizontal engine. If there are any other advantages we are unaware of them. Examining the points of objection against the horizontal engine, we will first consider the cylinder. In point of fact the wear is little, if any, greater than in the beam engine, and the seat of wear, instead of being at the bottom of the cylinder, as most of those who object to the arrangement conclude, in view of the weight of the piston, that it must be, is confined almost entirely to the upper part of the cylinder. The side of a cylinder next to the ports is always somewhat softer than elsewhere, owing to the greater mass of metal there; the lubrication is not so abundant at the top as at the bottom, and if the piston chance to blow a little steam, the abrasion thereby caused in a horizontal cylinder will necessarily be on the upper side. A cylinder of good metal is a long time, however, in wearing, whatever may be its position, unless, of course, it is under the care of a careless engine-man. It is not, however, every kind of pig-iron that will serve for a cylinder. Those of Messrs. Penn's engines are of Madeley-wood No. 3 iron, and several of the locomotive makers have found an advantage in mixing a moderate quantity of wrought-iron turnings with their pig metal, the result being *an iron of great hardness*, while, except in very

large cylinders, the mixture will run very uniformly. The great cylinders, from 70 to 112 inches in diameter, employed for screw engines, wear very slowly indeed. In the horizontal engine the piston is much more convenient of access, and the packing is likely, therefore, to be looked after with more care. When, too, the cylinder does become worn, it may be easily and quickly bored anew without moving it from its bed, the portable boring apparatus now largely adopted in railway workshops being employed for that purpose. As for the parallel motion, that might be easily enough applied to a horizontal as well as to a beam engine, and indeed a Wiltshire agricultural engineer has actually adopted radius rods for the horizontal piston-rods of portable engines. We do not, however, approve of 'parallel' motions. In the first place, the motion thus given to the piston-rod is not mathematically rectilinear, and cannot possibly be made so. But, more than this, with the least inaccuracy in original adjustment, or, what is more likely, that resulting from slight wear, the radius-rods throw a heavy strain upon the piston-rod. With a horizontal engine, if the crank is made to turn in the proper direction, the pressure of the cross-head is always upward upon the guides; and as the upward pressure due to the angularity of the connecting rod is not great, relatively, where the rod is long, its weight and that of the cross-head tend materially to diminish the friction upon the guides. The mean inclination of the connecting rod to the guides should not, and need not, exceed 1 in 10 throughout the stroke, and the friction due to this pressure should not exceed, and probably would not be as much as, one-tenth of this pressure, or the one-hundredth part of the actual steam pressure on the piston. This is without making allowance for the weight of the connecting rod and cross-head, which might diminish the upward pressure due to angularity to an amount which would not probably involve a loss in friction of the guides amounting to one-half of 1 per cent. of the whole power of the engine. The whole friction, however, upon the guides of a horizontal engine can hardly be as much as that brought upon the crank-pin and main bearings of a beam engine, in consequence of the worse than useless strain exerted upon them, at every stroke, by the momentum of a heavy and rapidly vibrating beam. A moment's reflection must show the loss of power in changing the motion, sixty times a minute,

of a beam many feet in length, and weighing several tons. Indeed the presence of the beam prevents the adoption of that speed of piston at which, all things taken into account, steam-engines work most economically. This remark applies, of course, to both beams and side levers, the latter typifying the worst form of beam engine. It would be useless to consider the working of a beam engine with 22-in. cylinders and 4 ft. stroke at 60 revolutions per minute. The strain caused by putting the beam into motion and bringing it abruptly to rest 120 times in a minute would be very great. It is this impracticability of rapidly vibrating a heavy beam that has retained the old standard of 220 ft. to 250 ft. of piston per minute so long in use. Remove the beam and the other parts of the engine are perfectly adapted to work at twice that speed, the heaviest engine in the navy working regularly and constantly at nearly 500 ft. per minute, while there is really no difficulty in working at an even higher speed. It is because of the necessity for slow speeds imposed by the beam that such absurdly heavy masses of machinery are to be found in our cotton-mills, flour-mills, and breweries, and sometimes, we regret to say, in the factories of engineers who should know better. Other things being equal, and provided only that the supply of steam is sufficient, the same engine may exert 100 or 400 actual horse-power, according as it may be driven at, we will say 20 or 80 revolutions per minute, and conversely, a quick working engine may give off the same power as a slow moving engine, and with a saving of from one-half to two-thirds of its weight. Quick speeds require, at most, only a moderate extension of the bearing surfaces, the work in any case being supposed to be carefully done.

"That the preference for a heavy rather than a light job has had something to do with the recommendation of the beam engine by so many constructing engineers we may reasonably suppose. There are other engineers, however, not less well-informed, nor less successful in the character of their work, who prefer horizontal engines, and are able to assign good and sufficient reasons for their preference. As more generally constructed, there is no doubt that horizontal land engines have not had the advantage of the same workmanship which has been expended upon beam engines, and this circumstance is unfortunate as tend-

ing to the prejudice of the most mechanical arrangement of the steam-engine, instead of being interpreted, as it should be, to the disgrace of the workman. Excellence of material, design, proportions, and workmanship should be accorded alike to beam and horizontal engines, and it will then soon appear that the latter are the most deserving of preferencè.

"Some of the principal Scotch paper-makers have adopted, or are about to adopt, horizontal single-cylinder engines, and we find that, with either one or two cylinders, horizontal engines are slowly working their way into flour-mills. Even setting aside their great advantage in point of first cost we are convinced that, with first-class workmanship, they will ultimately prove themselves superior in every respect to beam engines."

The whole argument, we may here remark, on quick speed *versus* slow speed engines may be simply summed up in a few questions. First, What constitutes the primary power in steam-engines? Clearly it is the evaporation of water,—in other words, the formation of steam. It follows from this that the boiler is the true source of power; and, therefore, the *actual* power obtained must always depend upon the capabilities of such a boiler for generating steam. This capability, in its turn, depends upon the exact amount and arrangement of heating surface, coupled with a proper proportion of grate area. The boiler then is the primary generation of power in the shape of steam, *the engine*, simply a secondary machine for the economic conversion of such power into *work* or mechanical effect.

Now the form and nature of this engine is merely a matter of economy, in which many circumstances require consideration. Primarily, we aim at economy of steam or heat, and consequently, fuel. According to "Joule" the theoretical equivalent of one unit of heat (that amount which would raise one pound of water through one degree Fahr.) is equal to the work of raising 772 lbs. through a height of 1 foot. Now our very best engines do not realize more than 30 per cent. of this. This points to serious defects somewhere; it shows us that we have a large proportion of power escaping from the chimney or funnel of our boiler. It also points to the probability of our engines being constructed upon a wrong principle, or, at least, not upon the best principle.

The most economical and generally adopted engine is that

constructed upon the reciprocating piston principle; but at best, this of necessity wastes much power. Take, for instance, the case of a locomotive, whose piston-rods, cross-head, &c., weigh 1 cwt. or more, this reciprocates through a course of 2 feet, and performs 200 double strokes per minute. In such a case we have a mass of material of 1 cwt. put in motion by the force of the steam, at a speed of 800 feet per minute, and brought suddenly to rest again by the effects of a further quantity of steam, either in the shape of a cushion from the exhaust and lead, or at the expense of a heavy strain on the crank-pin. Now, in this alone we have an insurmountable barrier, preventing us from obtaining anything like economical results. A rotatory engine, theoretically speaking, is the best in principle, and is the only engine which will give the best results; this, however, practically speaking, does not yet exist, and it therefore remains for future skill and ingenuity to work out the problem of an efficient rotatory engine.

Returning, however, to the consideration of circumstances which affect the nature and form of the engine, we may say that, besides the main object, namely, economy of fuel; simplicity and durability of construction, as also economy in first cost and space occupied by the machine, are also matters of great importance.

Now this brings us directly to the subject before our notice, and the argument is a simple one. Why should we put down huge and costly engines with large cylinders and with a slow speed of piston, when, practically, the very same effect will be obtained by an engine one-third the size, but with a speed of piston three times as great? *The same amount of steam will be converted into mechanical effect* in the smaller engine as in the larger, and with quite as economical results; it is, therefore, nothing more or less than a waste of material and valuable space to employ a large engine when we can get as much work from a small one.

But amongst other objections against running engines at a high speed, are the great wear and heating of journals; this, with ordinary slow working engines, would no doubt be too much the case, but that is the fault of the journals and general construction. Let the bearings of such an engine be in length from $2\frac{1}{2}$ to 3 times the diameter of the shaft, and well fitted, at the same time cleared away at the sides, so as to give the shaft a good bottom

bearing of about one-third of the circumference, and no fear need be entertained for such journals heating at high speeds as long as they continue to be lubricated. Such improvements as this would inevitably take place, but for the prejudice of some old-fashioned makers, and that absurd and confusing term *nominal horse power*, in view of which many are misled into the conception, that simply diameter of cylinder constitutes power; others, that it is stroke or pressure of steam; and in short, no two agreeing as to what really constitutes horse power. On the subject of such rules or terms in engine construction the *Mechanics' Magazine* says:—

“There are few subjects on which more books have been written than the construction of the steam-engine. The beauty of the scientific truths involved; the grace, so to speak, displayed in the movements of the finished machine; the fact of its being, to a great extent, the basis of our whole social system, the source, not alone of our wealth, but of our luxuries, the spirit ministering to all our necessities, could not fail to constitute it an attractive object to scientific authors. By some it has been handled poetically; by some philosophically, scientifically, mathematically, popularly; by very few, sensibly; and, in spite of the mass of printed matter which bears on the subject, considerable difficulty is experienced in gathering any really useful information from existing books. We need never be in doubt, it is true, on any matter connected with it, provided we are content to take certain guides, and trusting ourselves wholly in their hands, progress towards the results to which they would lead us; but if our minds are unfortunately so constituted that we cannot quietly submit to accept one guide, without inquiring into the merits of others, we at once find ourselves adrift, for each proposes to lead us to the same goal by roads differing widely in direction and smoothness. Such, perhaps, will always be the case, and we regret it, for the fact has proved more injurious to the steam-engine, and a more powerful cause of delay to its progress, than ignorance or direct prejudice on the part of the constructive engineer ever could have been.

“The assertion that the steam engine is, in one sense, the most imperfect source of power we possess, may be startling; little reflection is requisite to prove it true. We can hardly be said to possess any other mechanical source of motion, save falling water. Animal strength and the force of the winds may prove

very useful under certain limitations, but they play a very inferior part in our manufacturing economy as compared with water. Both from the antiquity of the use of this power, and from the extreme simplicity and invariable character of the laws on which its energies depend, everything relating to it has become thoroughly well known; and very little difficulty is experienced in constructing a water-wheel which will give forth a useful effect or modulus, equal to 70 or 75 per cent. of the theoretical useful effect due to the fall of which we avail ourselves.

"In the steam-engine, on the contrary, we find a machine whose entire success depends on the accurate acquaintance of the engineer, not only with laws scarcely yet well defined, but also with the exact applicability to each or any of them to certain cases and circumstances, which must always be exceptional, and vary with different engines. The question of fixed rules for steam-engine construction becomes as a consequence complicated to the last degree, and presents difficulties sufficient, in our opinion, to have long since banished them from anything pretending to be a sensible book. The difficulty of practically carrying out theory; our comparative ignorance of what theory really says truthfully on the matter; the exigencies of diverse situations into which the steam-engine has to be fitted, as travellers were on the bed of Procrustes—have all operated very effectually in preventing its average of useful effect approaching even distantly to the practical perfection of the water-wheel or turbine. Instead of 70 or 80 per cent., we realise about 30 per cent. of the power due to the combustion of the coal consumed; in other words, we burn three times as much coal as we ought.

"But one thing can set this great evil right; for it is a great evil, regard it as we may. Teach our engineers an accurate knowledge of the principles involved; but, for the sake of progress banish for ever the collections of arbitrary and dogmatical rules with which the shelves of our libraries, and our brains are equally burdened. We do not mean to assert for a moment that certain rules are not useful; nay, we will go so far as to admit that, to a certain limited extent, they may be absolutely indispensable; but this can only be the case when they are made use of for the purpose of avoiding grave errors, not as being in themselves guides to success. Their proper function is to point out

the course of construction which is positively wrong, not that which is absolutely right. Their use once narrowed to this, their legitimate province, they become serviceable. In the present state of things they are not only worthless, but to the last degree mischievous.

"The steam-engine differs from nearly all other machines, in that its success depends, not on one, but a multitude of principles, each to a certain extent demanding the observance of certain rules of construction, most of which are incompatible one with the other when the various principles are combined to form a whole. Not so, perhaps, provided we had infinite space in which to erect our engines, but this not being the case, our assertion is in the main correct. Thus, a heating surface, as compared with grate surface, three times what it is now, would be very advantageous provided it were attainable on board our steam-boats, but unfortunately it is not, because the principles which guide us in the construction of the marine boiler must submit to the influence of those which regulate the construction of a ship. To go further apart from what we may term external agencies, we find internal features and working necessities, which frequently lead to wide deviations from correct principles, which may clash in their application to such an extent that each must yield to the rest. We might fill volumes with instances of the kind, but they are so obvious as scarcely to need illustration at our hands. We will point out one. On correct principles of water-heating, we should deprive the waste gases from a furnace of all excess of temperature above that of the water within the boiler. So far so good; but, on looking further, we discover that to ensure rapid combustion, when that is necessary; the gases must possess a very much higher temperature in order that they may ascend the stack with sufficient velocity.

"In short, the more we go into the question, the greater we find the difficulty of applying any fixed or arbitrary rules to the steam-engine, the only machine which is commonly employed to supply motive power. The water-wheel and the wind-mill are instruments depending for their success each on a simple principle. The steam-engine derives all its energy from many different principles, which permit not only considerable latitude *individually* in their application, but positively cannot be em-

ployed in combination, without, to a certain extent, sacrificing much that renders each most perfect. We ask, then, how can fixed rules properly apply to a machine complicated in its form and a hundred times more complex in its principles? Were it possible to draw up a code of laws which would be applicable to every varying circumstance, different form, and varying purpose under which it is found, or to which it is applied, they would form a book so gigantic that it would be valueless; no one could read it, none comprehend it. Even were such a book compiled, and granted that it was absolutely perfect now in 1863, who could say with certainty that it would be equally correct in 1873? The last ten years have ushered in wonderful changes, and we feel little doubt that the coming ten years will produce results equally important.

"The engine of James Watt bears little or no resemblance to the engine of the present day. His was colossal, magnificent, mighty in its appearance of power. The tardy giant certainly conferred blessings on the manufacturing world, such as no motive power which had gone before had ever done. But this giant was costly to keep, slow in his movements, and his size and beauty formed but a useless pageant. The condenser came to be looked on as the most essential part of the engine—the source of all its power. We, half a century later, have learned that it is but a useful adjunct, a means of realizing the last fraction of economy, but not in any way necessary or indispensable to the development of power from the combustion of fuel. But all the rules at present employed by steam-engine builders date back, with scarce an exception, to the reign of Watt, and are, as far as possible, forced into modern practice, whether applicable or not. As well might we retain the old hemp-packed piston, as the exact area of grate, or speed of piston, which the engineers of Watt's day gave us.

"We may certainly apply empirical rules to the construction of a boiler, the speed of a piston, the height of a stack, &c.; but, *cui bono?* A different description of coals may render our boiler next to useless; the speed of piston adjudged to us may entail heavy multiple gear—a difficult situation may render expedient the employment of an engine constructed apart from all such rules. *Of what avail, then, is it to print and publish, day*

after day, dogmas which can be of no general value, because they are not capable of general application? Why fix the speed of a piston at 300 ft. per minute when we find it do its duty equally well at 100 ft. and 1,100 ft. per minute? Why fix positively the area of a grate, when a little difference in the state of the air, in the quality of the coals, in the skill of the fireman, can alter the results obtained? Let our engineers rise above such narrow dogmatism; let them handle the subject liberally; let them study as carefully as they will the scientific truths involved in the working of every separate part of the machine they propose to construct: let them display their talents in the combination of these different parts, guided by an accurate and well-trained perception of that course of construction most suitable to the circumstances in which they have to act, not blindly following rules which alter not, like the laws of the Medes and Persians."

The most improved and most economical engines now introduced are the combined high and low pressure engines, the steam cylinder being wrought highly in expansion. On the merits of such engines a most excellent paper was read before the Civil and Mechanical Engineers' Society, by Francis Campin, of which the following is an abstract:—

"The economical results accruing from the expansive method of using steam are now so universally known, that further argument upon the merits of that system, except as to the degree which limits its practical utility, is needless; but I now desire to direct your attention to the comparative merits of double and single cylinder expansive engines.

"The mode of employing steam expansively by the closing of the valve before the termination of the stroke of the piston, was discovered by Watt in 1769, but he did not apply it until 1776, nor was it patented until 1782. The double-cylinder engine was invented by Hornblower in 1781, and was subsequently combined with Watt's condenser, by Woolfe. From these dates we find that the double-cylinder, or Woolfe's engine, was invented very soon after the advantages of the expansive system were perceived, and down to the present time it has had numerous and important advocates; but, on the other hand, there are those who contend *that the present adoption of the Woolfe engine is a retrograde step.*

"We find by searching amongst the patent records that even at the present time the Woolfe engine is very highly esteemed by some engineers of undoubted experience and ability; at least such is the conclusion drawn from the numerous patented inventions by which it is endeavoured to render that engine more practically useful, and to approach more nearly to the theoretical efficiency.

"Let us now examine the action of steam in the single-cylinder engine and in the Woolfe engine, it being supposed that the steam is allowed to expand to four times its initial volume; let us suppose our single cylinder has an area of 400 square inches, and that the steam has an initial pressure of 40 lb. per square inch absolute pressure and the vacuum perfect; the effect of the steam in the passages being neglected at present; during the first quarter of the stroke the initial pressure will be maintained, after which it will gradually diminish to about 8.75 lb. per square inch, giving an average pressure for the entire stroke of about 23.11 lb. per square inch, or 9.244 lb. average gross pressure on the piston.

"The difference of pressure during the stroke is 31.25 lb. per square inch, which is equal to 74.125 per cent. of the maximum pressure.

"We will now see how matters would be in a Woolfe's engine under similar circumstances: let it consist of one small cylinder of 100-in. area, and a larger one of 400-in. area. The pressures are supposed to be as before. The effective pressure in the small cylinder will be 40 lb. per square inch minus the mean back pressure; the back pressure of course varies from 40 lb. down to 8.75 lb. during the stroke, the average being 17.485 lb., which, being deducted from 40 lb., leaves 22.515 lb. per square inch, or 2,251.5 on the small piston. As the pressure per square inch on the large piston varies from 40 lb. to 8.75 lb., the mean effective pressure will there be 17.485 lb., making 6,994 lbs. on the whole piston. Hence we have for the mean gross pressure on the two pistons 9,245.5 lb., almost exactly the same as on the one piston in the last example, and as the difference is so minute (less than $\frac{1}{8000}$), I shall take the two quantities as equal.

"In this case the mean pressure on the two pistons is 18.45

lb. per square inch, nearly. The pressure on the small piston at the beginning of the stroke is 40 lb. per square inch, with an equal back pressure; therefore, the effective pressure is *nil* at the top of the stroke on the small piston. The effective pressure on the large piston is 40 lb. per square inch at the top of the stroke, so we may call it for the two pistons 32 lb. effective pressure per square inch. At the end of the stroke the effective pressure on the small piston will be 40 lb., minus 8.75 lb., equal to 31.25 lb. per square inch; that on the large piston will be 8.75 lb. per square inch, making the mean pressure on the two pistons equal to 13.25 lb. per square inch. The difference between the maximum and minimum pressures will, therefore, be 31.25 lb., minus 13.25 lb., equal to 18 lb. per square inch, or 57.6 per cent. of the maximum.

"It is, of course, taken for granted that both pistons act upon one shaft; then the method above adopted, of distributing theoretically the pressure over the gross area of the two pistons, gives the same per-centage results as would be obtained by taking the gross pressures on the two pistons instead of the pressure per square inch.

"We thus find that the differences of steam pressure in the single and double cylinder engines, working at the degree of expansion above mentioned, are, during one stroke, 74.125 per cent. and 57.6 per cent. of the maximum pressures respectively; hence, the Woolfe engine will work more steadily than the other, the variation of steam pressure being 22.29 per cent. less.

"Summarising the inferences drawn from the above calculations, we find:

"The single-cylinder engine is simplest and smallest, and the Woolfe engine works most uniformly, and the cylinders are exposed to least pressure in proportion to their diameters.

"In the next place, it is necessary to notice the causes which have hitherto militated against the general introduction of the Woolfe engine, and the obstacles to its practical success.

"As usually constructed, the double-cylinder engines have very complex steam passages and valves, in which expansion of the steam takes place without producing any useful effect. The loss happens thus: when the vacuum is produced in the large cylinder, *it, of course, extends itself to the steam passages as far as the*

valves; and as soon as a communication is again made with the small cylinder the steam will expand and fill such passages, thereby being reduced in pressure, and therefore less energetic in its action on the large piston than it would have been had those passages between the valve and cylinder been absent. The length of these passages will, of course, depend upon the construction of the engine, but their cubic contents will generally be found large in proportion to that of the small, or high-pressure cylinder.

"Another disadvantage has consisted in the extra space required by the Woolfe engine, which amounts to that taken up by the small cylinder. This is evident from the fact that, at the end of the stroke, the whole of the steam used is contained in the large cylinder, and for equal bulks and pressures this cylinder must, therefore, be as large as the one in the single-cylinder engine.

"These appear to me to be the chief objections to the Woolfe engine; and that these may, to a great extent, be obviated by means of recent inventions, I shall subsequently endeavour to show.

"Having observed that the extra space required by the Woolfe engine is exactly that occupied by the small cylinder, it follows that this should be made as small as possible in proportion to the large cylinder; the size of the cylinder, as far as regards the space it occupies, may be reduced in two ways—first, by using a higher degree of expansion; second, by altering the form and position of one or both cylinders.

"The limits of the first mode of reducing the comparative size of the small cylinder depend upon the pressure which it is safe or convenient to use, and the size allowed for the large cylinder; with regard to the second means of reducing the space occupied, we may observe that numerous patents have been taken out for arrangements in which the high-pressure cylinder is so placed as to occupy what would otherwise be waste space: thus, in some cases, the smaller cylinders are placed upon the top of the larger, and connected by means of piston-rods with the piston of the large cylinder through which the power is transmitted.

"The form of the cylinders is made another subject of various patents; thus, it is by one proposed to construct the larger cy-

linder in annular form, so as to surround the smaller one, but in this arrangement, as in others before alluded to, the steam passages between the cylinders must be lengthy, and this is a very great evil.

"Some time since Mr. Craddock constructed some Woolfe engines which worked with great economy; but I am inclined to think that for this he was rather indebted to his peculiar form of boiler and the high pressure at which he worked his engines than to any particular superiority in the latter.

"It has recently been proposed to construct double-cylinder engines so that the cranks of the shaft, which the pistons of the two cylinders act upon, may be placed at right angles to each other, so as to gain the advantages of the coupled engine in addition to those of the double-cylinder engine; in this arrangement, however, it is evident that the piston of the high-pressure cylinder must make a half return stroke after completing its stroke before the steam can be admitted to the low-pressure cylinder; and, in order to allow this, it becomes necessary to establish between the two cylinders a kind of reservoir, in which the steam is stored until the low-pressure cylinder is ready to receive it, and from which it may also be drawn after the communication with the high-pressure cylinder has been closed. Let us now examine, relatively, the work done by a given amount of steam in this and in an ordinary double-cylinder engine.

"Let the small cylinder be 100 in. in sectional area, and the larger 400 in. sectional area, the initial pressure of the steam being 40 lb. per square inch, then this will evidently expand down to 8.75 lb. per square inch during the stroke of the large piston. Let us determine the work done by one cylinder full of steam, the mean back pressure on the small piston will be 17.485 lb. per square inch, which, deducted from 40 lb., leaves 22.515 lb. per square inch effective pressure, making $2,251\frac{1}{2}$ lb. pressure on the small piston, and taking the stroke as 2 ft., the work done in the small cylinder will be 4,503 lb. raised one foot. As the pressure in the large cylinder varies from 40 lb. per square inch down to 8.75 lb., the mean will be 17.485 lb. per square inch, giving 6,994 lb. pressure on the piston, and for the work done in one stroke 13,988 lb. raised one foot, which, added to

the work done in the small cylinder, makes a sum of 18,491 lb. raised one foot by one cylinder full of steam.

"Now let us examine the case of the double-cylinder engine with the cranks at right angles; let the dimensions and pressures be as above, and let the reservoir be twice the size of the small cylinder. We must in the first place examine the variation of pressure in the reservoir; at the termination of the stroke of the large piston it is evident the pressure in the reservoir will be the same as in the large cylinder, viz., 8.75 lb. per square inch. At the termination of the stroke of the small piston we have the cylinder full of steam at 40 lb., and the reservoir, twice the bulk of the cylinder, full of steam at 8.75 lb. per square inch. Hence, when a communication is opened between the small cylinder and reservoir the pressure in the two vessels will become 19 lb. per square inch; the small piston now begins to return, compressing the steam in the reservoir till at half stroke, when the pressure in the reservoir will be 22.5 lb. per square inch. The communication between the reservoir and large cylinder will now be opened, and the large piston will begin to move, the pressure falling till, when the small piston is at the end of its stroke and the large piston at mid-stroke, the pressure becomes 13.5 lb. per square inch; the communication between the reservoir and high-pressure cylinder being then closed, the large piston finishes its stroke, the pressure behind it falling to 8.75 lb. per square inch, when the communication between the large cylinder and reservoir is closed, leaving the pressure in the latter the same as at the beginning of the stroke.

"From these figures we find that the mean effective pressure on the small piston is about 20.62 lb. per square inch, making 2,062 lb. pressure on the piston, and 4,124 lb. raised one foot each stroke. Similarly we find in the large cylinder an effective pressure of 14.56 lb. per square inch, making a gross pressure of 5,824 lb. on the piston, and 11,648 lb. raised one foot per stroke; then the sum of the work done per stroke in the two cylinders will be 15,772 lb. raised one foot.

"Comparing the two engines, we find that under the circumstances above-mentioned, the reservoir necessary in the double-cylinder engine with the cranks at right angles reduces the work done by a *given quantity of steam* from 18,491 lb. to 15,772

lb. raised one foot, a loss of about 14·7 per cent. It may here be observed that there would of course be the same loss in this engine compared with single-cylinder expansive engines, so that the ordinary coupled engines, with cranks at right angles, would be far superior to the above-mentioned form of Woolfe's engine.

"I have now to direct your attention to the improvements made in Woolfe's engine by Mr. Syrett, whose engines appear to be the most successful double-cylinder engines yet erected. In this form a longer stroke is given to the high-pressure piston than to the low-pressure, so that the former has a greater velocity than the latter, when such can be done; but the most important part of the invention consists in the arrangement of the valves, which are so placed as to avoid the useless expansion of the steam in the passages and steam chest. Let us now see the amount of saving thus effected, taking in the one case the ordinary form, and in the other the improved construction, and supposing the engine to be of the same dimensions as in the last example, the steam pressure being also the same.

"The contents of the small cylinder will be 2,400 cubic inches, and the passages through which the steam would have to pass from the small to the large cylinder would contain about 120 cubic inches at least, and in this space there would of course be a vacuum at the moment of beginning to make a stroke.

"When the communication is made between the large and small cylinder, the steam at once expands into the passages, and the pressure is reduced from 40 lb. per square inch to 36 lb. per square inch, making a mean loss of 2 lb. per square inch pressure during the whole stroke, which is equal to 11·4 per cent. of the mean effective pressure. If the valve is so arranged that the passage above-mentioned lays between the valve and the high-pressure cylinder, it will be filled with high-pressure steam when the small cylinder is filled, by which an addition to the mean effective pressure in the large cylinder will be made equal to about 1 per cent., which, added to the saving of 11·4 per cent., makes 12·4 per cent.; from this, however, we must make a deduction for the extra steam required to fill the passage.

When the stroke of the small piston is about to commence, the passage will contain steam of 8·75 lb. pressure per square inch,

the quantity of steam at 40 lb. requisite to fill this space will, therefore, be about 96 cubic inches, or 4 per cent. of the quantity required for the whole stroke; thus we find that in the present case, even with the small passages here supposed, the saving in them alone by the improved method of construction is 8·4 per cent., and here I have not considered the saving effected in the steam chest.

"Instead of going into further calculations regarding this engine, it will be more satisfactory to quote an instance of its application to practical purposes.

"In 1860, the patent improvements were made upon an engine driving a flour-mill at Halsted, in Essex. It was a single-cylinder engine, and, according to the proprietor's statement, drove three pairs of stones, with a consumption of 16 cwt. of coal per diem; the cylinder was 18 in. in diameter; two 5 in. high-pressure cylinders were added, constructed as above-mentioned, and the engine was then found capable of driving four pairs of millstones with a consumption of only 12 cwt. of coal per diem."

DIVISION THIRD.

LOCOMOTIVES AND OTHER TRACTION ENGINES.

In this department of engineering, the march of improvement for the past year, or indeed for any one year, is comparatively small. The rich display of locomotives, however, in the International Exhibition of 1861, showed many improvements, and established many important facts in connection with the locomotive and its accessories. The most prominent among these were the extensive use of coal and consequent apparatus for the consumption of smoke. High centre of gravity in most engines. The plan of constructing boilers having fire-box shells and smoke-boxes level with the barrel of the boiler, thereby giving greater strength as also economy of production. The almost universal application of Giffard's patent water-injector for feeding boilers. The application of *Allen's straight link motion*, a link, without

doubt, giving the very best results either in full gear or expansion. Our experience of this link, as also that of the Scottish Central and North British Railways, is, that it is more economical in repairs and first cost than any other, while it gives most accurate results in the distribution of steam in the cylinder, the "lead" being nearly constant for all degrees of expansion, while the ease with which the link is reversed, owing to its being "self-balanced," is a great advantage. The material from which most of the working parts of locomotives are made, promised in future to be chiefly steel, produced principally from cast-iron, it having begun to find its way into practice with the best results. Many difficulties will, however, yet have to be overcome in the working of such steel, such as hardening large pieces without the cracking and twisting so often accompanying such operations.

The tendency in locomotives is—owing to increased speed and consequent boiler power—an increase of weight, but it seems rather anomalous that enormous dead weights, such as 30 and 50 tons, should be propelled over our lines for the purpose of gaining sufficient tractive force to draw a few carriages of perhaps only 50 or 100 tons more. Yet such is the case, and the experience of our railways of late has been, that power and speed cannot be attained without consequent weight in the locomotive. What the introduction of steel as a material for the different parts of a locomotive (boiler included) may do to reduce this remains to be seen. Certainly such enormous weights are not absolutely necessary to the power and speed of the locomotive beyond their being inseparably connected with the present known materials from which we fashion the parts requisite to obtain such power.

The *Engineer* on this subject says,—“Every part of a locomotive engine must inevitably have weight, and a certain amount of weight is, *per se*, desirable, in order to give adhesion to the driving wheels. For the latter purpose, however, every express engine is from two to three times too heavy, even without its tender, while of the 50 tons of a first-class engine and tender, the adhesion of 10, or at most 12, tons would generally suffice for the heaviest express traffic. There is, therefore, a very wide margin for the reduction of weight in locomotives, provided only that adequate strength can be retained. We may remember, in the meantime, that the very weight of the locomotive and tender

often amounts, in the case of express trains, to one half, or more than one half of the total weight moved. The problem, therefore, is somewhat simpler than that of the reduction of the weight for a given power by say one half, for, in proportion to the reduction of weight, less power is actually required. To move an engine, tender, and a train of 50 tons, or say 100 tons in all, at the rate of 50 miles an hour over an ordinary good and nearly level railway, at least 400 indicated horse-power are required, and with very moderate gradients from 500 to 600 horse-power would be necessary. But if the carriages could be drawn at the full speed with an engine and tender of but 30 tons, not more than 300 horse-power would be required on the level, and in the same proportion less than the 500 or 600 horse-power necessary on gradients with the heavier engine. If, upon any given system of construction and general scale of proportions, 400 indicated horse-power be obtained from an engine which, with its tender, weighs 50 tons, only $37\frac{1}{2}$ tons total weight should be required for 300 horse-power. But if we assume that the resistance, equivalent to 300 horse-power, will, with a train of 50 tons, admit of an engine and tender of but 30 tons, let us inquire whether it be not really practicable to bring down the weight of our present heavy express engines, including tender, to about that standard. In other words, cannot the weight of locomotive engines be diminished, through improved construction, to the extent of one-fifth of their present weight, a fixed total amount of weight being in any case reserved for the driving wheels, to insure their adhesion to the rails?

"Let us first refer to the general proportions of the engine, apart from the dimensions of the boiler. One way of accumulating weight in locomotive engines is by adopting driving wheels of great size. Now it would appear almost unnecessary to observe that only an increase in the evaporating power of the boiler can really increase the power of a locomotive engine. With a given boiler, a large wheel and large cylinders cause a positive loss of power by entailing increased weight, the resistance of which can only be overcome at the sacrifice of tractive power, otherwise commercially and mechanically applicable to the movement of useful load. Thus, with a given size of boiler, and a given pressure of steam, a 15-in. cylinder, 20-in. stroke, and 5-ft.

wheels, have precisely the same tractive power, and can draw the same train at the same speed, as an 18-in. cylinder, 24-in. stroke, and 8ft. 8in. wheel. Exactly the same steam would be used in each case, but the pistons of the smaller engines would, at fifty miles an hour, move at the rate of 933 ft. per minute, while those of the larger engine would run off but about 650 ft. A high speed of piston presents no disadvantages whatever if ample wearing surfaces are provided, it being only necessary to have larger steam and exhaust ports for a given diameter of cylinder, in order to admit a correspondingly greater volume of steam in a given time. We may be excused for mentioning that the Americans work small-wheeled engines at a good rate of speed, say 40 miles an hour, and that for a 16-in. cylinder, steam ports 14in. long by $1\frac{1}{4}$ in. are about the smallest employed, while for 15in. cylinders there are instances of ports 17in. to 18in. long by 1in. or $1\frac{1}{4}$ in. wide. The valves have a maximum movement of from $4\frac{1}{2}$ in. to 5in., at which steam is admitted for upwards of 90 per cent. of the stroke, the movement of the valve, when cutting off at three-eighths stroke, being $2\frac{1}{4}$ in., which with a lap of $\frac{3}{4}$ in. at each end of the valve, gives an opening of the steam port of $\frac{5}{8}$ in.— $\frac{1}{4}$ in. of which, when running nearly in mid gear, is lead. The American engines have cross-head bearings of great size, a series of four guide bars, two above and two below the piston rod, being provided to each cross-head. The guide bars are, each, from $3\frac{1}{2}$ in. to $4\frac{1}{2}$ in. wide, giving from 7in. to 9in. of total width, while the bearing of the cross-head is from 14in. to 16in. long. Many 16-in. cylinder engines made in America have one square foot of bearing surface on each face of each cross-head—one square foot of bearing against the under side of the upper bars in running forward, and the same extent of surface on the upper side of the lower bars in running backward. With such proportions, and connecting rods of from 3 to $3\frac{1}{2}$ times the length of the stroke, almost any speed of piston is practicable, the higher the speed, of course, the lighter being the parts required to develop a given amount of power.

"Now, comparing an engine with 15-in. cylinders, 20-in. stroke, and 5-ft. wheels, with another having 18-in. cylinders, 2-ft. stroke, and 8ft. 8in. wheels, it is evident that, even with a roller of exactly the same size in each, the former would weigh

several tons less than the latter, probably six tons less. And yet the two engines, providing only that a given fixed weight, say twelve tons, was retained upon the driving wheels of each, would not only have the same absolute power, but the lighter engine, with equal power, would draw a load about eight tons heavier than that of which its rival would be capable. Practically, therefore, the smaller engine, having six tons less weight, would be the more powerful of the two. But, leaving out of consideration for a moment the opportunity for drawing a heavier load, the boiler of the small engine might be somewhat diminished in size, and still be capable of supplying steam for drawing a load equal to that taken by the larger engine. If we make the comparison between 17-in. cylinders, 24-in. stroke, and 7 ft. 6 in. wheels, and 15-in. cylinders, 24-in. stroke, and 6-ft. wheels, we have, with a given steam pressure, the same tractive power in each, and with an increase of piston speed one-fourth greater with the 6-ft. than with the 7½-ft. wheel, we shall consume an equal amount of steam in a given time, and take trains of equal weight at the same speed. Yet the 15-in. cylinder engine, even with a boiler of the same size as that of its rival, would weigh probably three tons less.

"Experienced locomotive engineers are aware that the quick reciprocations and more frequent blast of a small-wheeled engine, running at a given speed, are attended with a lessened consumption of fuel. This fact was particularly illustrated a few years ago, in working two classes of engines, the one with large and the other with small wheels, on the old Oxford, Worcester, and Wolverhampton Railway. It was found that, in every respect, the best results were obtained with the smaller wheels.

"If to the opportunities for diminishing the weight of a locomotive by adopting smaller wheels, and correspondingly smaller cylinders and a higher speed of piston, we add those which still exist for the diminution of weight or increase of pressure in the boiler and other parts, and the saving which the adoption of tank engines will allow, it is almost difficult to say to what an extent reduction of weight may not be carried. In the boiler, for example, it is believed to be entirely practicable to employ welded joints, thus dispensing with riveting, with its great loss of strength, and the tendency which appears to be often induced, in the case

of riveted seams, to longitudinal 'furrowing,' already the cause of several fatal locomotive boiler explosions. It is found, also, on many lines, that the dome may be dispensed with with entire success, and, clearly, with a considerable saving of weight. The saving by the use of steel axles and tyres is already considerable, driving axles with journals only $5\frac{1}{2}$ in. in diameter being now employed in express engines with 16-in. cylinders and 7-ft wheels. Even the Injector permits of a saving in weight.

"An opportunity for a very great saving in weight is offered in the arrangement of the tank engine. The only object in carrying a large supply of fuel and water is, of course, to enable long distances to be run without stops. Yet $1\frac{1}{4}$ tons of coal will carry the heaviest express from London through to Rugby, and although nearly 9 tons of water are required, it has already been found practicable to 'pick' this up when the train is under way. 1000 gallons of water, weighing $4\frac{1}{2}$ tons, would, one would suppose, be the most which an express engine need ever carry, and thus, if the supply of fuel and water be carried upon the engine, a weight of 6 tons at most should suffice for every really necessary purpose of the tender now carried, the weight of which occasionally exceeds 21 tons."

A correspondent writes to the same paper (*the Engineer*), on the subject of Light Locomotives, as follows:—

"It appears anomalous to use a machine weighing from one-third to one-half the load it is required to draw, to convey the said load to its destination, yet we are doing this every day of our lives. We use engines weighing from 30 to 40 tons to convey trains whose weight averages from 40 to 50 tons only, unless in exceptional cases. It must be allowed that we cannot move a pound one inch without the expenditure of a certain amount of power, which power represents money. With regard to a locomotive, increase of weight also entails another source of expense, viz., the wear and tear of permanent way, and this last item is rendered a very serious one from this cause alone, without considering any other. It must needs be a strong and well-laid rail that has to bear the crushing load of a 40 ton engine, crashing over it at fifty miles an hour. No wonder if engineers find their road anything but a permanent way under such treatment.

"This, however, is not what I would seek to draw attention to so much as to the expense of the engine itself. Railway statistics show the cost of each ton carried over each mile of ground, so that, in other words, every ton of dead weight moved over any space, however small, represents a certain amount of money taken out of the dividends. It is true that we cannot obtain forty miles an hour from a light engine—but why? for the simple reason that the term 'light' is merely a relative one, and means that the engine is small, and therefore light; or in other words, the term 'light' is sometimes improperly used for the more correct one 'small.' We cannot then get a high speed from a small engine. The only influence that weight could exert would be to retard instead of increasing speed. An engine that has to convey large trains at a high speed must have large heating-surface and boiler-room; to carry this large boiler we require a strong and heavy framing, and from this increase of weight we are compelled to go a step further, and provide wheels and springs of suitable strength to bear the load with safety, which entails another increase of weight, so that increase No. 1 brings us to increase No. 2, and both these bring us to a third increase: and so, like a boy's snowball, it goes on accumulating till it assumes a formidable magnitude. Even here, however, we are not contented, but actually increase this weight wantonly, by the addition of heavy iron foot-plates, which is considered requisite to give the 'driving wheels sufficient bite' to enable them to draw their loads. Now, this last item might surely be done away with by proper distribution of the weight, and hanging the engine so as to get most of the weight on the driving wheels. That this is already done to some extent I am aware, but still so long as we are (or think we are) obliged to increase the weight for the sole purpose of gaining adhesion, I do say the principle is imperfectly carried out. We have ample, indeed I say too much, weight already at our disposal for this purpose, if brought to bear to its utmost extent, so that the want of 'bite' should not justify the use of unnecessary weight.

"To make our locomotives lighter without diminishing their power, I would suggest the following methods:—The use of steel for the boiler and all other places where it could be introduced. That we should try how far the plan of welding instead

of riveting could be adopted in making the boiler, as it promises greater strength than rivets, and by this means we might have as strong a boiler with $\frac{1}{4}$ inch plates as we now have with double that thickness. The slides should be fitted with a good balancing apparatus, so as to reduce their friction to a minimum, which would enable us to use a lighter 'motion.' I would make the piston rods hollow, and the connecting rods should be made—if flat, of a I section; or, if round, hollow: the motion-rods being made in the same way. I would abolish the tender altogether, and make the engine on the tank principle, thereby gaining all the weight for adhesion; and, to increase this latter, I would couple two pairs of wheels. I do not see why even express engines should not have 'coupled' wheels, which, with the use of equalising bars, would secure all the weight almost for the driving wheels. The 'steam dome' I would also dispense with, as it costs more and causes more trouble than it can compensate for, and weakens the boiler materially, which weakening could not be afforded with $\frac{1}{4}$ inch plates.

"I would use a comparatively small tank, only large enough in fact to contain water for a run of ten or fifteen miles. To supply the engine with water for a long continuous run, I would introduce a far more extended use of the trough between the rails, having one at every station for each line of rails. The water could be easily kept from freezing by not letting it into the trough till a short time before the train was 'due,' and at any important station the water would have no time to freeze. Where the stations were too far apart, I would have tanks and troughs placed under the management of the milesman who had charge of that portion of the line, or some other suitable person, so that there would be always an ample supply of water. The cost of laying down and keeping those troughs in repair would be little compared to the saving by having light engines, and getting rid of those cumbersome tenders. I would likewise allow very limited room for carrying coal, only sufficient to bring the engine from one stopping place to the next, with sufficient margin, of course, for contingencies. There would be little expense in maintaining a supply of coal at each station for the use of that portion of the line. Coal trains in most cases passing so frequently would form a ready

source of supply, and in exceptional cases a truck load could be sent by any of the numerous goods trains. It is ridiculous, the notion of sending coals to a great depot—perhaps forty or fifty miles distant—to be carried back again by the various engines to which it may have been served out—a considerable portion of it thus going over the line twice. Were it possible to fancy a series of turnpikes established on a line of railway, and that the locomotive engineer had to pay so much a ton for his engines passing through, I feel certain we would see a vast diminution in their weight in a very short space of time. But it is with railways now as it was with steamships some years ago—interests in the latter were not amalgamated. The shipbuilder cared nothing about adapting his hull to the engines, and *vice versa*. So it is with the locomotive engineer and the civil one now, the former does very little for the road, and the latter as little for the engine; but if, as already said, the latter could charge tonnage for the use of his road, and the former for any ‘derailment’ that would occur, we should see considerable improvement, both in the safety of the public and in the amount of the dividends. Practically, this is impossible; but if we have reason to think that under stimulants we could attain improvement, we ought to try to get it without such adventitious aids.”

Upon the subject of smoke consumption, and the application of Giffard’s injector, the “Mechanics’ Magazine” makes the following remarks:—

“The introduction of good coal as a substitute for coke has become almost universal on all the railroads in Great Britain, the saving effected being very considerable, amounting to many thousands per annum on such lines as the North-Western. All things considered, the production of smoke from coal-burning engines is not very great, and with a little more care might possibly be reduced to half what it is at present. Even now, however, it can scarcely be considered a nuisance, except by the fastidious. With a roomy fire-box, and a free admission of air above the fire, almost any coal can be burned without smoke. It is not easy to secure these conditions, however, in the locomotive. The furnace doors are far too small to supply all the air required if perforated ever so closely on Wye Williams’ prin-

ciple; and their fire-boxes are too confined to permit flame to exist in them as freely as it ought. Theoretically the gases should remain in the box till consumed, a condition impossible to secure completely. The scoop deflector has been introduced as a substitute for the perforated fire-door, and the brick fire-bridge to detain the gases and aid their combustion. These, combined with a long grate and a deep fire-box, give better practical results than can be derived from the use of the combustion chamber, which is rapidly going out of favour. The employment of this expedient—to designate it by its proper name—entails a shortening of the tubes, which is fatal to economy, and materially hastens the destruction of the smoke-box and stack. An increase in their number, and reduction in their size, as practised at one time on the East Lancashire line, where 427 tubes of $1\frac{1}{8}$ in. diameter were crowded into a shell of but 3 ft. $8\frac{1}{4}$ in. outside diameter, has given anything but good results, either in the economy of fuel or the durability of the boiler. Mr. Williams and many others have endeavoured, ere now, to prove that length of tube was superfluous, inasmuch as experiments showed, that evaporation was almost wholly confined to that portion of the tube surface next to the fire-box. Most of these experiments were made with model boilers, employing gas jets to produce the necessary heat. The results obtained were fallacious. We have every reason to believe that a locomotive boiler with 2 in. tubes evaporates a very considerable quantity of water close to the smoke-box when travelling at a high speed. It is taken for granted that flame will not enter a 2 in. flue for any considerable distance; this is perfectly true with a moderate draught. When the fire is urged, however, by the powerful action of the blast-pipe at high speed, such flues become filled with flame from one end to the other if not more than 8 or 9 feet long. Any engineer can determine the fact for himself by drilling a few sight holes in the smoke-box door. It is well known that by exposing a Davy lamp to a strong current of air, flame will be forced through the wire gauze, and accidents have ensued ere now from this cause. Flame will not enter small tubes from precisely the same reason that it will not pass the gauze meshes of the lamp; but the opposing force can be overcome without difficulty, and nothing is easier than to compel flame to enter

and traverse a tube of moderate diameter. How much smoke may be consumed (to popularize the action which takes place) within the flues of a locomotive boiler, is a subject well worthy of careful inquiry. Large and long flues may, after all, be quite competent, when aided by a roomy fire-box, to supply all the space necessary for tolerably perfect combustion, without entailing any of the difficulties which beset the combustion chamber, and, as experience proves, without any risk of wasting fuel; for more heat is lost in permitting the escape of unconsumed gases through small flues, than can possibly follow from the use of large flues, which, although they offer less heating surface, yet render that surface more valuable by permitting the existence of flame within them.

"Though locomotives consume the products of combustion moderately well, we have no reason to conclude that their efficiency, or the economy of fuel burned, is as yet anything like what it should be. The average evaporative duty of the locomotive boiler does not much exceed 8 lb. of water converted into steam, for each pound of coal put into the fire-box. Lord Donald succeeded, years ago, in evaporating nearly 13 lb. of water, for each pound of coal consumed, in a marine boiler not of the best type—a result generally attributed to slow combustion. Experiments conducted in France, however, fail to confirm such a conclusion, as the employment of a forced draught, with quick combustion, was proved beyond dispute to add equally to the efficiency and economy of a boiler properly constructed, though not specially intended for the employment of the principle. The straight sides of the locomotive fire-box—or, worse still, those which are wider at the top than at the grate—are extremely unsuitable for communicating heat to the water surrounding them. A vertical surface is certainly not more than half as efficient as one steeply inclined over the fire, a film of steam remaining continuously in contact with the plate, and preventing that absolute contact of the water with it which is essential to the rapid production of steam. Mr. Sinclair, of Glasgow, constructed the fire-boxes of some of his small locomotives with inclined sides with the greatest advantage, and the principle deserves general adoption. It reduces the size of the tube-plate, however, so much, that in order to carry it out as it should be,

grates must be made much wider than they now are—a difficult job on the narrow gauge, from the position of the trailing and driving wheels. Anthracite coal-burning engines have been successfully constructed in America with grates 7 ft. wide across the track, and as much as 6 ft. long. Were such enormous grates adopted here, it might be found advantageous to cover them round the sides with fire-bricks, which would protect the plates and conduce materially to the regular production of steam. A thinner fire, too, might be maintained on the grate with manifest advantage, as far as the prevention of smoke is concerned.

“The feed-pump is rapidly being displaced by the injector. On the North-Western it is only retained on a few old-fashioned engines, as much, perhaps, for the purpose of comparison as from any other reason. A feed-pump, filled with air-vessels and all the requirements necessary to hydraulic machinery, driven at a high speed, is really rather a complicated piece of machinery, easily put out of order, and exposed to risk from frost, &c. We understand that on the Eastern Counties line, where the application of the injector is all but universal, a very considerable saving is effected in the item of feed-pipes alone. Not one has ever burst when the injector is employed, while with feed-pumps of the best construction they were continually being ruptured, either by the irregular action of the pump or by frost. The engines, too, are found to keep their steam better when running, if the boiler is fed by the injector than when supplied by a pump. There is little doubt that the expenditure of steam is far greater with the former for equal quantities of water fed in than with the latter; but this really is a matter of very little consequence when we consider the advantages held out by the injector. The simplicity of its arrangements, the ease with which it can be fitted, and, we may add, the certainty of its action under all the varying circumstances to which a locomotive is exposed, render its application one of the most important improvements the locomotive has received of late years.”

On the subject of some of the internal disturbing forces of locomotive engines, a paper was read by A. W. Makinson, M. Inst. C. E., before that society. The following is a recapitulation of such:—

"The author stated that, although the permanent way of railways had been much improved of late years, it was still a question for inquiry, which was proposed to be undertaken in the present paper, whether, having regard to the safe transit of passengers at the high speeds now demanded on trunk lines, the locomotive engines were as free as possible from such internal disturbing forces as had a tendency to cause them to leave the rails.

"In elucidation of the subject, the indicator diagrams taken from the cylinder of the 'Great Britain' locomotive on the Great Western Railway, in 1847-49-50 (*vide* Clark's 'Railway Machinery'), at the velocities of 26, 35, and 52 miles per hour respectively, were selected for examination; and from these a series of diagrams was constructed, which exhibited graphically the different forces acting in a locomotive when in motion, numerical values being assigned to each of those forces.

"The disturbing forces were divided into two classes—first, those which were generated by the revolving parts of the engine, as the crank, crank-pin, and half the weight of the connecting-rod; and secondly, those which were generated by the reciprocating masses, as the piston, piston-rod, cross-head, and half the weight of the connecting-rod, &c. As it was understood that, in the practice of the first locomotive engine makers, the proper counterbalance for the revolving appendages was now always applied, that class was not considered.

"The nature and origin of the second class of forces were then examined in detail. It was observed that, if the circular path of the crank-pin around the axle was divided vertically by a straight line through its centre, then the crank arm would approximately coincide with this line, when in its positions both of greatest and of least velocity; and while the crank-pin moved through 180° from its position of the greatest to that of the least velocity, the reciprocating appendages developed pressures in favour of the motion of the train, but when it moved from the position of the least to that of the greatest velocity, these appendages offered resistances to the motion. It was shown that, in general terms, the pressures generated by the *vis inertia* of the crank arm were the greatest at the end of the

to the mid-stroke; the pressure during the second half of the forward stroke and the first half of the back stroke assisting the motion of the train, and during the second half of the back stroke and the first half of the forward stroke opposing the motion of the train.

"It was only by adding the pressure thus developed by *vis inertia* to the simultaneous steam pressure, that the total efficient tractive power generated at any moment in either cylinder could be arrived at. The variation in amount of the tractive power throughout one stroke of the piston was thus seen to be much greater than when the steam pressures alone were considered. By adding together the amounts of tractive power simultaneously developed in the two cylinders of the ordinary engines, with cranks at right angles to each other, the total tractive force on the train at any point in one revolution of the driving wheel was arrived at; and the diagrams exhibited showed the great irregularity in amount of the total tractive force, operating to produce fore and aft motion in the engine and train. By comparing with each other the amounts of tractive force developed simultaneously in the two cylinders, the tendency to sinuous motion in the two-cylinder engine was shown, and exhibited graphically in one of the diagrams.

"In conclusion, the author submitted that a single-cylinder engine would be free from all sinuous motion: that at 26 miles an hour it would have about the same, and at higher speeds far less, fore and aft motion, than the ordinary two-cylinder engine; that by supplying the driver with the means of exerting about as much power as was expended in putting the engine in motion, a single-cylinder engine would have equal capacity for work with the two-cylinder engine: and that the use of single-cylinder engines for passenger traffic would, by reducing the weight of the carriages, render railway travelling less uncomfortable; by reducing the cost of locomotive power, and the expense of the road; whilst the dead weight of the engine and the wear and tear of the several parts, would be diminished.

"The appendix contained mathematical formulæ showing: 1, the relation between the pressure on the piston as observed by the indicator, and the pressure on the crank-pin; 2, the disturbing force ge

to the mid-stroke; the pressure during the second half of the forward stroke and the first half of the back stroke assisting the motion of the train, and during the second half of the back stroke and the first half of the forward stroke opposing the motion of the train.

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"The appendix contained mathematical investigations and formulæ showing: 1, the relation between the pressure on the *piston as observed by the indicator*, and the equivalent pressure *at the crank-pin*; 2, the *tractive force generated by the un-*

balanced revolving masses; and 3, the pressures, referred to the crank-pin, generated by the *vis inertia* and varying velocity of the reciprocating parts of a locomotive in motion."

In the discussion which took place at an ensuing meeting "It was argued that the lateral motion of railway trains was not attributable so much to imperfections in the locomotive engine as to defects in the permanent way, which it was difficult to keep in perfect order, from the variations in the temperature, the changes in the weather, and other causes. The tendency of the reciprocating masses to produce oscillatory motion must be relatively less than formerly, owing to the greater weight of the present engines. It was doubted whether the re-introduction of the single-cylinder engine would result in any advantage, as the difficulty of starting a train with such an engine would, under certain circumstances, be insurmountable; and the effect of having only a single central cylinder would be to raise the centre of gravity of the engine, thus creating a serious objection. The late Mr. George Stephenson had endeavoured to equalize the motion, by the adoption of a three-cylinder engine which had been in use for many years on the North-Eastern Railway. In that case there was a large cylinder in the centre, and two smaller ones at the sides; but the cost and the complication of the parts of that engine prevented its general adoption. It was, moreover, doubtful whether, even at the highest velocities, there was any apparent difference in the steadiness of that engine, as compared with others in which the revolving and the reciprocating masses were well balanced. However perfectly an engine might be balanced when it left the manufactory, after it had been running for some time, from numerous causes the springs required re-adjustment.

"As regarded the disturbing forces which were said to arise from the pressure of the steam in the engine, it was contended that the unbalanced pressure upon a bearing at any time was only that due to the force driving the engine by that particular bearing. If it were possible to suppose a case of a locomotive with only one wheel, such an arrangement would no doubt tend to produce sinuous motion, with a force proportioned to the distance of that wheel from the centre of gravity of the engine. But with two wheels keyed fast upon the same shaft, of such strength as not to yield appreciably under torsion, there could be no differ-

ence of pressure (of this kind) between the two sides of the engine; and that was true wholly irrespective of the number of cylinders, or of the places where they were put. An engine capable of producing 1 ton of tractive force must distribute it over the two bearings, and there would, therefore, be $\frac{1}{2}$ a ton on each bearing. Even if the engine were driven by one cylinder, it was manifest it could not put a pressure upon one side of that engine which was not equalled by that on the other side at the same moment; and that there could not possibly arise any sinuous motion from the driving pressures. Referring to the disturbances caused by the momentum of the parts, it was observed that, though the force of the parts in motion increased as the speed became higher, the times through which they acted decreased; for it could be shown, that the distance, through which these forces were capable of moving an engine, must be the same for all velocities.

"As to the distance which the forces spoken of ought to move an engine, it was demonstrated that, with a locomotive the crank shaft of which was making three hundred revolutions a minute, with a length of crank pin of 1 foot, producing a velocity of 63 miles an hour, and the moving parts belonging to each cylinder of which engine weighed 500 lb., the total weight of the machine being from 27 to 28 tons, there would be an amount of motion equal to only 14-100ths of an inch. And it must be remembered, that while this would be the extent of each motion, the number of such motions, as they occurred at each revolution of the crank shaft, could not increase for a given distance travelled over, although from the greater number of revolutions per minute of a high velocity over a low velocity, there would be a greater number of revolutions in a given time.

"Supposing, however, that the disturbances were as great as had been represented, then a better remedy than the single-cylinder engine would be, either the plan introduced by Mr. Bodmer in 1834, and modified by him in 1841, of having two pistons in one cylinder, both the piston-rods issuing at the same end, one being made hollow to admit of the passage of the other; or the duplex engine brought forward at the late International Exhibition by Mr. Haswell, the Engineer for the Austrian States *Railway Company*, who proposed to employ four cylinders—two

for giving a forward, and the others an aft motion. It was stated that, in the year 1836, the late Mr. W. Weallens had designed an engine with four cylinders, similar in every respect to that last referred to.

"It was suggested, that the Paper would have been more complete, if, as well as pointing out the forces tending to produce lateral motion, or oscillation, the measure of the effects of those tendencies had been calculated. Taking the forces exactly as given by the author, it was remarked that the total lateral translation, to the right or to the left, in the mass of an engine by those forces, would be in one case 1-5th of an inch, and in another 1-10th of an inch; and at the velocity of 35 miles an hour, each of those forces would act during about $\frac{1}{4}$ th of a revolution; and that as there were two revolutions in one second, the diagrams represented forces acting during the $\frac{1}{8}$ th part of a second. The result of this theoretical investigation had been to show, in a visible form, a series of tendencies which certainly existed, and knowing where they existed, however slight, precautions could be taken to diminish their effect. It was evidently most important to allow sufficient play between the flanges of the engine and the rails,—that they should not fit too closely. It was considered that the estimated amount of the oscillation was so slight, that any great deviation from the established form of engine could not be recommended: certainly not the substitution of a single-cylinder engine, with all its mechanical inconveniences, for the present double-cylinder locomotive.

"With regard to the effect produced by the unbalanced reciprocating parts of an engine, it was thought that the 1-5th of an inch could not be accepted as the real measure of the sinuous motion of most engines. In practice it had been noticed that, even with a good road, the lateral oscillation amounted to 2 inches, and if the road was in bad order, then it would be much more. But this did not express the evil in its true form; as it was (or might be, at any instant that the flange was in contact with the rail) a question of the amount of force exerted against the rail, tending to bend the rail, or to break the chair. As to the balancing of the reciprocating masses, direct trials were required to show the alterations necessary to be made in the positions and weights of the parts, before the best result could be arrived

at. There were many objections to a single-cylinder engine, besides the difficulty of starting the train. Among these, the irregularity in the tractive power, in place of a somewhat distributed force, was alluded to, as likely to cause a jolting action, which might give rise to accidents, from the fracture of the couplings; and it was shown that, when using full steam throughout the stroke, the maximum and minimum rotary power of the double-cylinder engine varied in each quarter of a revolution of the cranks, nearly in the proportion of 14 to 10, whilst in the single-cylinder engine the variation was as much as 20 to 0. It was suggested that the most uniform rotative power would be obtained by using two cylinders, and cutting off the steam a little before and a little after the half stroke. Further, it would be a great improvement, if locomotive-engine builders, in common with marine engineers, would use steam-jackets, both to the cylinders and their covers.

"It was believed that the discrepancy between the amount of the lateral motion produced by the disturbing forces as calculated and as found in practice, arose from the circumstance, that the theory was based upon the supposition that the wheels were without flanges. When the direction of the course of an engine at a high velocity was suddenly altered by any disturbing force, the undulation of the engine brought the flanges into violent contact with the rails, and the elasticity of the rails caused the engine to rebound, or rather glance off, against the opposite rails. When the rebound happened to be simultaneous with a disturbing force acting in the same direction, the maximum oscillation was caused; but the rebound was in some degree neutralized, when the disturbing force acted simultaneously in the opposite direction. In support of this view it was adduced, that the oscillations of an engine were not coincident with its pulsations, as they would be in the theoretical case of an engine without flanges; but that they were very irregular, sometimes extending over a period of eight or ten pulsations.

"In the deductions as to the extent to which the oscillation of the engine was occasioned by the varying operations of the steam in the cylinders, the whole weight of the engine had been taken into account; whereas, it was contended, that only that *part of the mass* which was upon the springs ought to be con-

sidered. The motion communicated to this portion of the bulk of the engine would be in excess of the estimated results; but even then, the amount of oscillation which was known to exist would not be arrived at. With a perfect road, and an engine accurately adjusted, it was not possible to put that engine exactly straight upon the rails. Nor could any slight defects, such as the wheels being out of truth the one-hundredth part of an inch, be detected. Neither were there any means of investigating the extent to which these defects prevailed, because they might be acting either together, or in opposition to each other, and thus might aid, or retard the oscillation, or the tendency to oscillation, which the backward and forward pressure of the steam in the cylinders must occasion to the boiler and other parts connected with it.

"In reply upon the discussion it was remarked, that if all oscillation was to be referred to defects in the permanent way, it might be asked, why travelling on a railway worked on the atmospheric principle was so decidedly superior, in ease and steadiness of motion, to travelling on a line worked by locomotives. It was believed it had been established in the paper, that even if the permanent way were mathematically perfect, locomotive engines of the ordinary construction would create lateral and oscillatory movements of a grave character at high speeds, and results similar to those produced by numerous small depressions in the level of the rails. It had been maintained, that any oscillation in the engine, produced by the internal disturbing forces, would be the same at all velocities. This involved two erroneous assumptions. It had been taken for granted, that the time allowed for the oscillation varied inversely with the velocity of the engine, and that the disturbing force varied directly as the velocity. Now it had been shown, in the diagrams, that at 26 miles per hour there was a tendency in the engine to make two oscillations in each revolution of the driving wheel, whilst at 52 miles an hour there was a tendency to one oscillation only, in each revolution; so that the time allowed for an oscillation was the same, whether the train was moving at 26 or at 52 miles per hour. The pressures tending to produce oscillation were opposed by the friction of the wheel on the rail. *The difference of these two pressures was the moving force pro-*

ducing transverse motion; and whether this friction was assumed to be the one-fourth or only the one-tenth of the insistent load on the wheel, the moving force increased more rapidly than the velocity. Applying the same dynamical law which had been employed by several speakers, for calculating the measure of the effect of the tendencies to lateral movement of the front end of an engine while running, it was shown that, even so well-proportioned an engine as the 'Great Britain,' at 52 miles per hour, with a greasy state of the rails, would twice in every revolution of the driving wheel move laterally $\frac{1}{4}$ of an inch, and would strike the rail with the wheel flanges. A blow, once originated, between the flange and the rail would, from their elasticity, entail a series of blows at regular intervals of time; and should any of the series coincide in time and direction with the constantly recurring impulses to transverse movement originated by the engine, a heavier blow between the flange and the rail would follow; and this would be repeated, so that it was conceivable, that the pressures shown on the diagrams, occurring simultaneously with the rebound of the wheel from the rail, might ultimately induce a lateral pressure great enough even to drive the flange of the leading wheel up the rail, and so to cause the engine to leave the rails."

A good recapitulation of the past improvements, &c., and other innovations in the construction of locomotives, appears in the following article extracted from the "Mechanics' Magazine:"—

"Notwithstanding the dictum contained in Clark's 'Railway Machinery,' we cannot regard the link motion as otherwise than imperfect. Its comparative excellence we admit; but with the growing tendency for higher pressures and early cut-off, its defects become day by day more prominent. In order to maintain anything like a full pressure on a piston, moving at 800 or 1,000 ft. per minute—a speed frequently reached in express engines—it is essential that all passages leading to the cylinder should not only be short, direct, and of large area, but that they should be opened and closed with a velocity proportionate to the speed of the piston. Locomotives are seldom worked in the central notches, except when running fast. The travel of the valve is then shortened, and the ports not only reduced in area, but opened *and closed* with a tardiness, which greatly militates against the

advantage to be derived from an early cut-off, diagrams taken at high speed showing a very remarkable loss of pressure as the piston pursues its course through the cylinder. Steam is estimated to flow into a vacuum with a velocity equal to that due to a body of the same density, falling through a space equal to the height of a column of steam of the given pressure. By this rule, steam of 120 lb. pressure would flow into a vacuum at about 2,079 ft. per second; but the difference between the velocities of any two pressures is the velocity with which steam would flow into steam of a lower pressure. At the commencement of a stroke, or rather at the moment when the valve first opens, the pressure within the cylinder is comparatively trifling, steam then enters with great velocity; once, however, the difference in the densities of the steam in the boiler and that in cylinders ceases to be well defined, steam passes very sluggishly from the former to the latter, and is little able to overcome the resistance offered by long curved passages and the contracted areas of the steam ports. It is very unusual, in consequence, to maintain more than 70lb. in the cylinder at high speed, indicator diagrams falling at once on the commencement of the stroke, long before the steam is really cut off. The analyzation of such diagrams is not easy, as it is impossible to tell, without setting out and measuring the valve gear, when the valve really closed. Theoretically, the ports should be extremely short, straight passages, opening directly from the valve-seat into the cylinder. The great size of the valve required to suit such an arrangement has hitherto precluded its adoption. Mr. Clark gives us good reason to believe that as much as 25-horse power is frequently expended in working valves as it is—a positive waste of power which it would be very injudicious to add to. If, however, the valves are properly balanced, there is nothing to prevent the employment of any size deemed most desirable; and if we are to adhere to the link and eccentrics, the sooner we have a large valve with a long throw, and great lap, the better. We illustrate this week a form of balance-valve, which, although recently patented here, has been worked for some time in America with considerable success. Plainmaison's slide-valves have been adopted on the Chemin de Fer du Nord since the year 1861 with excellent results both in the Crampton *express* and Engerth goods engines. Railway

companies don't like change, however; and the general introduction of the balance-valve is, here at least, apparently as far off as ever.

"Quitting the subject of valves, and resuming the consideration of the means by which they are put in motion, we find existing arrangement lauded for a simplicity which they do not really possess. The link motion, consisting as it does of two eccentrics with their rods, straps, pins, &c.; a link often built up of many pieces; and a rocking-shaft with balance weights or springs; is really the most complex part of the engine. Its expense is very considerable at first; and from the rapid wear to which it is exposed, and the nice adjustment which it must preserve, its maintenance forms a large item in the working expenses of the locomotive. We are well aware that this must be a distinguishing characteristic of any valve gear whatever; but we believe that other arrangements not a whit more complicated will give better results. The mere fact of such a piece of machinery, delicate and finely wrought, answering its purpose so well, should rather encourage us in searching for a substitute which, not more simple, perhaps, would regulate the admission of steam to and its exit from the cylinders after a fashion approaching more nearly to theoretical excellence. Complexity is in itself no evidence of erroneous design. It only becomes reprehensible when it is introduced unnecessarily. In the construction of machinery, the end usually sanctifies the means; and there is no reason that a valve gear may not be very excellent, and very complex as well. In America, the use of the separate cut-off was long adhered to, and is even still held in high favour by many builders. At least one locomotive in the great Exhibition last year was so fitted, and it seems likely enough that its general adoption is not far distant. The variation in the lead, when the reversing lever is in different notches, is not the least objection to the link motion. The setting of valves is in consequence a positive science, and one understood, or at least practised, only recently. A few years ago it was quite exceptional to meet with a locomotive which 'beat' equally. Even yet there is great room for improvement on most of our great railway lines.

"The question of balance weights, at one time considered definitively settled, seems likely to be re-opened. It is extremely

doubtful that it is good practice to perfectly balance the reciprocating parts of a locomotive. One locomotive superintendent has removed three-eighths of the accurate counterpoise from his engines, with manifest advantage. The solution of the problem lies, we fancy, in the fact that the pressure on the piston does not accurately represent that on the crank-pin, when the engine is in motion, because it is modified more or less by the momentum of the piston, rod, and connecting rod—to such an extent, indeed, in some cases, that the strain on the crank-pin is much greater near the termination of a stroke than at its commencement, although the steam is early cut off. As the equalization of the impelling force on the crank-pin is extremely desirable, tending as it does to the steadiness of the entire machine, it is not improbable that a heavy cross-head, piston, and piston-rod may be better for high-speed locomotives cut off very early, than those of a lighter construction. There can be no doubt, however, that the wheels must be accurately balanced, and this rule is seldom or never disputed. In conducting experiments on the subject, care must be taken to distinguish between the conditions under which an engine is tried in the shed, and those under which it performs its work on the road.

“There is little tendency to alter the practice which deems a single pair of drivers sufficient for express engines. Locomotives intended for high speeds seldom or never are burdened with heavy trains, and with rails in good order they manage to proceed well enough, but, unfortunately, not without doing great mischief to the permanent way, in consequence of the excessive loads placed on the drivers to secure adhesion. Still there seems to be much weight in the arguments which are urged against coupling wheels over 7 ft. in diameter, which make 270 revolutions betimes in the minute. The momentum of an 8-ft. side-rod at such a pace would be something tremendous, and its fracture would lead to fearful results. For ordinary passenger trains there is no excuse for limiting the number of drivers to two; and coupled engines are rapidly getting into favour for this kind of work. For æsthetical as well as mechanical reasons, the second pair of driving-wheels should be placed behind the fire-box, not forward. If inside cylinders are adopted, the latter position throws all the work out of the horizontal line, and entails many

difficulties with the smoke-box and framing. A few large engines of this class are doing good service on the North-Western, between Birmingham and Stafford. The driving-wheels are, we believe, 6 ft. in diameter, and hence the cylinders do not come inconveniently near the ground.

"Steel tyres make their way rapidly into favour with locomotive superintendents, while the civil engineer regards them with unmitigated disgust, from their destructive effect on permanent way. Six or seven tons on a single wheel was, however, more than any iron tyre, possessing toughness enough to be safe, could bear without spreading; and to the employment of the hard irons which were resorted to as a remedy, may be attributed many of the accidents once so prevalent from the fracture of tyres. Railway companies have found it much to their advantage to purchase rails honestly made of good iron properly worked, instead of cheaper brands which proved utterly worthless. Steel tyres are not very injurious to such rails; still, a softer material is better for adhesion, cheaper to work, and perhaps safer, in some respects, than steel. If a tyre could be made one, with the wheel rim proper, there is no doubt that its durability would be considerably increased; not only would its resistance to spreading be greater, but the shocks and vibrations to which it is exposed would be transmitted to the entire mass of the wheel, instead of being more or less retained in the tyre. Under the present system, the tyre is exposed to a treatment nearly similar to that which it received in the rolling mill which gave it existence, the interior being nearly as much injured by the wheel rim, as the exterior is by the rail. Mr. G. S. Griggs, of the Boston and Providence Railroad, U. S., many years ago, set all his tyres on wood to avoid this action. The rims of the wheels are made with dovetailed recesses all round, running in the direction of the axle. Into these recesses hard wood-blocks, thoroughly dried, are firmly fixed with the grain running in the direction of the groove. The tyres are then shrunk on, resting wholly on the wood, which stands, say, an eighth of an inch or less above the surface of the wheel rim. Mr. B. Adams has brought out a far more elegant arrangement here. He introduces a continuous hoop spring, fitting within an internal groove in the tyre, between it and the wheel. Two of these hoops are, we

believe, employed at present, each about one-third of an inch thick and $3\frac{1}{2}$ in. wide. The wheel rim is turned slightly convex, and rests on the hoops, which of course surround it. Experiments conducted on the St. Helen's Railway, Lancashire, show that Staffordshire tyres, fitted to wheels on this system, have given first-rate results when put in competition with Krupp's steel, Swedish, and Hood and Cooper's best iron, fitted in the common way. Krupp's tyres have run 40,873 miles, Hood and Cooper's 20,798, Swedish 34,006, without requiring turning up, as an average mileage; while Staffordshire tyres fitted on springs, have run 55,138 miles, remaining in excellent condition. The engines had all 4 ft. 6 in. wheels, except the last, which had 4 ft., and their weights varied from 19 tons 15 cwt. on Krupp's, to 20 tons 6 cwt. on Hood and Cooper's, 23 tons 14 cwt. on Swedish, and 21 tons on Mr. Adams' tyres. The saving to the rails must be considerable, for tyres can only be worn out at the expense of the rails. This same question of tyres nearly concerns the prosperity of railway companies. The maintenance of the permanent way is one of the heaviest items of expenditure which they have to encounter; and as the destroying element is found in the wheels of the locomotive, every improvement of which they are susceptible should be applied to them, without regard to the primary outlay, which is certain to repay itself a hundredfold."

Smaller classes of locomotives have been introduced into contractors' work and collieries, and with the best results. Such engines are usually cheap and simple. They have mostly outside cylinders of small diameter and long stroke, and small wheels from 2 to 3 feet diameter. The speed never exceeds 10 miles per hour, so that the power or tractive force is mainly obtained by a great speed of piston. In such engines, however, unless the valve is wrought on the top of the cylinder, the ports are necessarily long, the cylinder being small in diameter, and being required to project from the frame far enough to clear the guide bars if the valve and gearing are inside the frames. On the manufacture and use of such engines the *Mechanics' Magazine* remarks:—

"Not the least item of expense connected with the working of a coal, or indeed any other mine, is the conveyance of its produce

to the place where it becomes useful. The sinking of shafts, the erection of pumping and winding machinery, nay, the very raising of the coal, or ore, to the surface—operations attended as they are with risk and expense in no slight degree—are, after all, in most cases, but preliminary operations, which require the addition of a means of transit, safe, expeditious, and economical, before the miner can hope to reap any return for his labour, capital, and skill. The railway station or the wharf is usually at a considerable distance from the pit's mouth. Blast furnaces, although at first erected as close as possible to the mine, in the course of a few years, or even months, exhaust the veins in their immediate neighbourhood, rendering the sinking of new shafts at greater distances a matter of necessity, hence the transfer of materials to supply them becomes a matter of serious importance to their proprietors.

“In the mining districts generally we see lines of railway, or tramway rather, laid down from the pit's mouth to the wharf, the railway station, or the blast furnace, on which waggons capable of holding from a ton and a half to three tons, or even more, are drawn in trains of two or more by teams of horses. These railways are for the most part of the rudest construction. The sharpest curves and steepest inclines are considered matters of little importance; contractors' rails worn to the last, and, when new, of all patterns, spiked in the most negligent fashion to sleepers, which are seldom replaced so long as a rail can rest on, without actually going through them, form the permanent way. Scarcely an attempt is made to keep the joints good, or the rails of an equal height; when, in addition, we remember that the gauge seldom exceeds 2 f. 6 in.—3 ft. being unusual, and 4 ft. seldom or never met with—we are very liable to draw the conclusion that a more unpromising road to work with locomotives cannot possibly be met with, even in the wilds of America.

“On much such a road, nevertheless, did steam, in the hands of George Stephenson, commence that great era of locomotion which is the distinguishing characteristic of the 19th century; but, although railways spread in all directions around us, the modern engineer, discouraged by the unpromising field, has failed to introduce the locomotive to any great extent, as a substitute

for horse labour, on such lines as George Stephenson had to deal with. Colliery proprietors and iron masters, believing it impossible to work locomotives successfully under the circumstances, prefer to employ expensive horse labour, contending, that any advantage to be derived from the employment of an engine would not compensate for the large outlay necessary to improve their roads to such an extent as they believe requisite to ensure the working of a locomotive with success. In many cases, too, the purchase of land necessary to straighten a line would entail an enormous expense; besides, rival proprietors' lines often cross one another, so that raising one might cause such an incline on another as to render it useless; all these things considered, we see apparently good reason why horse labour is still adhered to.

"Now, we believe that the conclusions which have led to this result have been arrived at too hastily, and without sufficient reflection—without, in short, a sufficiently careful examination into what the qualifications of the locomotive for such situations actually are. An acquaintance with it only when drawing heavy passenger trains, at a lightning speed, on a line so perfect that the first-class passenger may imagine himself passing over velvet, gives but little idea of the actual capabilities of suitable engines even on the worst roads, and under the most difficult circumstances. If carriages propelled by steam can proceed with ease, safety, and expedition, not only on common roads, but even down, ay, and up, our green English lands, how much more likely are they to succeed on a road into which at least they cannot sink? a road indeed, which, with all its imperfections, will permit a horse to draw twice as much as he can on the best turnpike. The construction of engines which will do good service in those cases, is not a problem which presents as many difficulties as we may imagine at a first glance. At a low speed, carriages, whether drawn by horses or propelled by steam, may proceed over even the worst track with comparative ease; and, we feel certain, that light locomotives with low wheels, and a very short wheel-base, may be worked with success on almost any of the lines now worked by horse-power. The loads to be drawn need, in no case, exceed 60 tons, or the pace 7 or 8 miles an hour—5 will usually be found quite fast enough for all ordinary requirements; and as the existing waggons, which will in most cases have to be

returned in active service, seldom extend 20 in. in height from the rail to the side beams, no possible advantage can be gained by placing the engine on high wheels, which entail a great deal of trouble in the attempt to keep the buffer-beam low enough to suit the waggons. A low wheel, too, insures a good blast in the chimney, by enabling the pistons to make a fair number of strokes in a minute. We believe that 2 ft. 6 in. will be found a good general diameter. As to material, nothing can be better than cast iron, with steel tyres. The rails in general are covered with so much dirt and grit, owing to their small elevation above the surface of the ground, that wrought iron suffers rapid wear. Steel tyres appear to deserve the high character they bear, for such purposes at least.

“Too much care cannot be taken to make the bearing of such engines stiff, as outside cylinders must be adopted, and these, of considerable diameter and at some distance from the frame, exert a powerful tendency to bend it; and, the imperfections of the road added to this, would quickly pull everything to pieces were not strong cross braces and plates introduced between the frames. For this reason, as well as another which we will refer to further on, the best practice would be to adopt some such arrangement as Forester used in his first engines—that is, to place the valve chests outside of the frame on the top of the cylinders, working the valves by means of a suitable rocking shaft. Although the engines first constructed on this principle gained the name of ‘Boxers,’ from their oscillation at high speeds, no objection can apply to them when running at speeds under ten miles an hour; and it was not the arrangement of the valve chests, but of the cranks, which caused them to fall into disfavour with engineers. When we remember that the space between the frames of an engine for a 2 ft. 6 in. gauge is but 20 in., when the frame is, as it should be, inside the wheels, we at once see the great advantage gained by the adoption of any arrangement which leaves that space unoccupied by machinery, and permits the introduction of strong plates between the frame to impart the necessary stiffness.

“As the wheel-base is generally very limited, owing to the unusually sharp curves generally met with on colliery railroads, *the distribution of weight becomes a very important consideration.*

As but four wheels are admissible, and they of course coupled, means must be adopted to secure sufficient weight on the leading pair for the purpose of adhesion, as well as the preservation of the permanent way, which, being weak, is quickly destroyed by overloading a single pair of wheels. This same distribution of weight is a very troublesome problem, from the fact that the fire-box, being wider than the gauge of the line by many inches, cannot go between the wheels, and, united to the weight of the foot plate, which must be of some size, to carry coals, far overbalancing the cylinder end of the engine; the light smoke-box proving no match for the heavy fire-box. We have seen it necessary to resort to a cast-iron buffer-beam in front, ere now, to get over the difficulty.

"A proper disposition of the centre of gravity may always be secured by placing the water tank between the frames under the front end of the engine, and fixing a large steam dome on the top of the boiler, as close as possible to the chimney. Where a wheel-base of 5 ft. or 6 ft. can be secured, this will invariably give a steady engine, although it may overhang the wheels as much as 5 ft. or 6 ft. at each end; and, in order to obtain space for a water tank in the situation named, it is evident that all the working machinery must be outside, with the exception of the link motion and eccentrics. Another advantage in placing the valve chest outside will be found in the ease with which steam-tight joints may be made and broken when easy of access, which they cannot be within the smoke-box or under an engine at once so low and narrow. The constant jolting, too, to which the engine is exposed is very apt to break the steam-pipe joints, unless some elastic arrangement is adopted.

"Ample cylinder room should be provided, to meet the exigencies of an undulating road; it is of little consequence if the boiler is unable to furnish full pressure steam to the cylinder for long periods together; they will seldom exert a constant drain on the boiler, and, besides securing economy (not, indeed, that this is of much importance in a coal district) by working in general on a high grade of expansion, will, with 100 lb. steam, give ample power for any possible exertion the engine may be called on to make in ascending a steep part of the road, &c. We know many lines which, in general tolerably level, have one or

two inclines of perhaps 1 in 30 or 1 in 40, a hundred yards long, or so. Over such inclines the train, from its slow speed, possesses no impetus to aid the engine—as the drivers say, ‘It is all dead pull.’ Large cylinders prevent any difficulty in such cases.

“Where machinery is already so much cramped for room, it is almost needless to say that a pump is inapplicable. A No. 5 Giffard Injector is superior in every respect; room is easily found for it on the foot-plate.

“Horses cannot compete in economy with light locomotives such as we speak of. The cost of fuel is almost nominal; and although we do not for a moment advocate bad roads, still we do not hesitate to say that in few cases need we be deterred by their imperfect condition from employing a locomotive suitable to their requirements. Money will be expended to advantage in improving such lines; this being done by degrees, may often be effected almost insensibly; every such improvement will well repay the outlay, by adding to the durability of the engine and reducing wear and tear.

“Everything which tends to cheapen produce confers a benefit on the consumer. The public generally are large consumers both of coal and iron, and we believe the introduction of light locomotives on colliery railroads a matter of some interest to the community at large.”

Amongst the most recent improvements in locomotive details those connected with the tyres of the wheels are specially deserving of notice. Formerly the tyres in use upon various lines were of the ordinary Staffordshire description; then it was found that “Bowling” and “Lowmoor” tyres were not too good, that a saving was effected by their use, even although such tyres were much more costly, until at last we find that steel tyres are coming more or less into use, and with the very best results, in both safety and economy. Quite recently, however, the whole system of *fastening* tyres is likely to be reformed. It seems anomalous that we should be procuring material of a costly nature to resist the blows to which it is subjected in the shape of a tyre upon the rail, and that we should also be introducing steel and “*case-hardened*” rails, when by other means it is possible to remove or *at least soften* such blows. This has been effected by Mr. Wil-

liam Bridges Adams, who has successfully introduced a hoop spring between the wheel and tyre. A pair of wheels having ordinary Staffordshire tyres fitted to them on this principle was exhibited at the international Exhibition after having run 55,138 miles without turning, longer indeed than any of Krupp's steel tyres under similar circumstances. Such a plan seems to us a most reasonable and common sense one, and we have little doubt that if the details of fastening such tyres on such a principle can be made secure that they will be generally adopted, as the saving must be enormous.

The following data upon this subject we quote from the '*Engineer*':—

"In the paper read by Mr. Thomas Spencer, at the last meeting of the British Association, upon the manufacture of steel in the north-eastern districts, he mentioned, as a matter of note, that one firm had commenced making circular springs, under Mr. William Bridges Adams' patent, to be employed between the tyres and felloes of the wheels of all kinds of railway rolling stock. 'It is stated,' said Mr. Spencer, 'that springs applied in this manner effect an increased durability in Staffordshire tyres of 50 per cent. over Krupp's cast steel tyres without springs.' We do not know whether Mr. Spencer be himself the licensee referred to, for if he be, one might be disposed to make some deduction from his statement, but we have, in corroboration, a report from the St. Helen's Railway, a mineral line in Lancashire, that Staffordshire tyres set on hoop springs have run 63,913 miles under heavy engines, and that even then, when the engine was in to be overhauled, the tyres did not require to be turned anew. Another engine of the same weight, and engaged in like work, and fitted with Krupp's cast steel tyres, had come in after running 40,800 miles, to have the tyres turned down. Krupp's tyres have run upwards of 100,000 miles, we believe, without requiring to be turned, but not under engines worked like those of the St. Helen's line, upon gradients of 1 in 35, and around curves of 300 ft. radius. No one can doubt that the principle of interposing a spring between the tyre and the wheel, in railway rolling stock, is correct, the durability and security of the application being a practical question to be settled by experience. *If the tyres could not be put upon springs without working off,*

or in some way endangering, the safety of a train, their introduction would be quite out of the question. But on the St. Helen's line (and this is by no means the only one upon which they have been worked), spring-seated tyres have run for considerable periods of time, under the driving wheels of coupled engines, and, so far, we believe, without exhibiting any tendency indicative of insecurity. The speed, of course, is not very high, but a mechanical arrangement which is safe at one speed ought to be safe at all speeds. We do not think the experiment would be a rash one if hoop springs were put under at least the coal trucks of other lines. If all went well, it would not then, we suppose, be long before they would be employed—where they are most needed—for express passenger stock. The experience gained upon the St. Helen's line points to a vast saving in the working of railways, for the mere saving of tyres is, in itself, a small matter. A saving of tyres represents a corresponding saving in rails, for the action and reaction between a tyre and a rail are necessarily equal. A saving of both tyres and rails implies a lessened strain upon all parts of the way and rolling stock—less wear and tear everywhere, and, consequently, a saving of *power* which wear and tear upon railways necessarily absorb. It need not be demonstrated that it requires costly engine power—coke, oil and tallow, and heavy repairs—to wear out tyres, batter down rails, break heavy chairs in two, and, generally, knock a strong line of railway to pieces. The principle of elasticity is acknowledged in the abstract, for it is almost absolutely certain that, without strong and yet elastic engine and carriage springs, it would be next to impossible to maintain either way or rolling stock at high speeds, or, indeed, to keep the trains upon the rails at all. Every railway manager and locomotive engineer understands this. But in locomotive engines we have the weight of the driving wheels, tires, driving axle, axle boxes, counterweights, and a part of the weight of the connecting and eccentric rods, besides a certain additional weight due to whatever friction there may be between the axle boxes and their guides—all unrelieved by springs. It is, of course, only the parts suspended upon the springs that derive direct benefit from the interposition of springs. *In all railway rolling stock indeed, a very large part of the weight is unrelieved in any way—a weight which is the most*

lifeless of all dead weight. Here, clearly, we require springs, and it is but the plainest conclusion from common sense that the elasticity should be provided as near as possible to the rolling surface. Perhaps the early American 'strap rail,' a bar 2in. by $\frac{3}{4}$ in., was the easiest and best permanent way for the very short interval of time before it became crushed into the longitudinal timber upon which it rested, or, which took place very often, before the end spikes came out, and the end of the bar was rolled up by the wheels into a 'snake's head,' which now and then thrust itself up through the bottom of a carriage among the legs of unsuspecting passengers! Still, if there could be such a thing as welding iron firmly to wood, the least thickness of iron which would afford a good wearing surface for a rail would be the best, unless, indeed, it were possible to seat the rail upon springs. As for the tyres, the application of springs appears to be entirely practicable and highly successful. We learn that the spring wheels do not slip on the rails, but that, occasionally, they slip a little between the tyre and wheel, and that no practical disadvantage arises from this. With the wheels lifted from the rails, the tyres can sometimes be slipped upon or around the wheel by hand, and yet the useful adhesion to the rail is not at all affected, and for a very obvious reason. The slight wear of the tyres permits of their being made much lighter than usual, other things being equal. A heavy tyre is a great evil, yet, ordinarily, it must be made heavy to provide for rapid wear. It is evident that, even on the score of safety, the increased security against the bursting of tyres, and from the results of axles severely strained by torsion, points strongly to the value of spring-seated tyres. The slight rocking movement which they appear to have on the wheel is found to save the flanges from being cut out, and yet, all the while, there is no evidence that the security of the engine, to which the tyre is applied, is endangered. With these results we are not surprised to learn that the St. Helen's Railway company are applying spring-seated tyres to all their engines, as fast as they come in for examination and repair."

Upon the subject of "gauge," the "New York Times" notices some of the doings of Congress in railway matters, as follows:—

"We are shocked to observe that Congress has not specified the *diameter of the Pacific Railway axles*—a subject not only of

vastly greater importance to the safety of passengers than the gauge of the track which Congressmen do attempt to dictate, but which legislation is equally competent to prescribe. It is true that physical laws have settled the principles upon which these and other engineering problems are successfully solved; but shall this great national highway dare to be unsafe and expensive when its mechanical details have formed the subject of Congressional orations? It is true that the steamship Foh Kim, on her trial trip, last week, did not cease to work economically when 'cutting off' short, even after they had opened Chief Engineer Isherwood's book against 'cutting off' short, and solemnly laid it right on the cylinder head; but however regardless nature may turn out to be of official opinions, shall any senator dare to face a constituency whom he has outraged by neglecting to ingraft some original notion of his own—good or bad, just as freaky nature is in the humour to consider it—upon the people's own railroad? What is the use of having any Congress, if engineers, plodding in a slough of traditions and formulas—and, we may add, soldiers clambering over the same rusty treadmill, as old as gunpowder—cannot for once be compelled to turn a short corner and conform to the supreme power of the land?

"Seriously, this official tampering with what is not professionally understood creates irreparable mischief—worse, perhaps, though of the same certainty, than the mischief that would ensue were a legislative body to assume the same familiarity with medicine that they do with engineering, and attempt to prescribe for their own ailments. For instance, this question of railway gauge. On Saturday last, Mr. Fessenden made the following statement in the Senate:—'It was a conceded fact that such a gauge (4ft. 8½in.) was too narrow. The best roads in England had altered their gauges, and some of them were 7ft. The reason why so many roads were built on this proposed gauge was because they had begun so, and having begun wrong, the thing had to keep on. But the wider gauge was safer, and susceptible of greater speed in travelling.'

"All of which is quite correct, with the trifling exceptions that the only gauge in England which has been altered is that of the Great Western, which has to a great extent been narrowed from 7ft. to 4ft. 8½in., so as to work cheaper and conform to all the

other connecting lines; and that the wider the gauge the greater the dangerous weight and friction in passing curves, and the less the speed with a given power. As Senator Harriss remarked, it has been proposed to narrow the gauge of the Erie road. Engineers have estimated that this alteration could be gradually accomplished at a cost which would in thirty years be saved out of repairs, not to speak of the ability to avoid transshipment in connecting with other lines. With a boiler and engine as heavy as the rails will economically carry, increasing the gauge beyond the standard simply adds length and weight to the axles and all the 'athwartship' parts of a locomotive or car—simply increases the load, without adding a particle of aid in carrying it. As to ease in passing curves, no gauge at all—a mere line—would offer no friction; and the more the narrowest possible limits are departed from, the greater the slipping of the wheels, the twisting of the axles, and the racking of the whole structure.

"But these considerations are of little moment, compared with the change of gauge from the common standard, to 5ft. as proposed—the immense cost and labour of unloading all the freight from the cars of the twenty thousand miles of 4ft. 8½in. railway, that may happen to reach the eastern terminus of the Pacific and reloading it upon the Pacific cars. If one principle in railway management is better understood than another, it is the great economy—the imperative necessity—of not 'breaking bulk' between connecting roads. In fact, the attempt to compel transshipments at Erie, Pennsylvania, by the dissimilarity of gauge, led to actual war; the people would not submit to the very inconvenience which the Government now undertakes to provide by law.

"There are three or four specially grave errors about railway transit with which the public is peculiarly enchanted, and some of which legislative bodies never lose the opportunity of saddling upon railway companies, if they can get the chance. A wide gauge is one. A heavy rail is another. About the time that the Legislature of this State made use of a 70-pound rail, as one of the conditions of the Hudson River Railway charter, the best practitioners in England were saving largely in repairs by reducing their rails to 60 lb., and even lighter. This very company *has been obliged to decline* more than one economical improve-

ment and means of safety in track, on account of this unwise provision. Still another popular error is big driving-wheels. We never saw an unprofessional inventor or schemer in railway machinery who did not propose about a 10ft. gauge, a 150-pound rail, and driver, like Lord Dundreary's American, 17ft. high; and we certainly never heard of a successful practitioner who did not reduce all these dimensions, even below a standard that is still employed on exceptional lines. In America, particularly, and latterly in England, where the highest speeds are attained, the size of driving-wheels is constantly being reduced, as locomotive economy advances. With proper counter-balancing and workmanship, small driving-wheels and a high-speed of piston economise both in weight and in the use of steam.

"Now, the question is, shall engineers, who have made these complex and difficult questions the study of their life, be intrusted with the regulation of engineering details, or shall unprofessional men, who, as a body, are not even amateurs—not even tyros—in engineering, undertake not only to jump at conclusions which are more than likely to embarrass this great enterprise for life, but to compel their adoption by law, so as to cut off all chances of remedy or reform? If Congress will just provide a feasible financial plan, authorise the employment of the best talent in the construction and management of the Pacific Railway, and then let the details severally alone, they will receive the thanks and praises of shareholders, passengers, freighters, and the public for centuries to come."

The expense of the maintenance of locomotives on railways forms a very material item in their total expenditure, but with the various improvements, such as coal burning, &c., is becoming much reduced on lines foremost in such improvements. The present expense of the working of the principal lines in Britain is shown in the following table, which we extract from the '*Engineer*:'—

"Allowance must be made, of course, for the greater relative difficulties experienced by some companies in obtaining combustible, &c., and the proportion of goods and passenger train mileage must also be taken into account. The London and North-Western mileage rate, however, seems too high, all things considered. It should be observed that the return for the Great Western comprises the West Midland, but not the South Wales,

SYSTEM.	Miles worked, Dec	Miles run by passenger trains.	Miles run by goods trains.	Total miles run	Number of locomotives possessed by company.	Total charges for motive power.	Cost of locomotive power per mile run.
London and North-Western, ...	1,054	7,959,494	7,724,804	15,684,288	972	£674,417	10½d.
Great Western, ...	816½	4,813,899	3,580,525	8,394,424	558	255,754	7½
North-Eastern, ...	789	3,313,154	6,329,233	9,642,387	446	279,450	6¾
Midland, ...	633	3,487,256	5,398,190	8,885,446	473	308,467	8½
Lancashire and Yorkshire, ...	375	3,415,300	3,001,020	6,416,320	363	194,827	7½
Great Northern, ...	405	2,715,124	3,605,505	6,320,629	338	215,215	8
Great Eastern, ...	647	2,951,069	2,286,719	5,237,788	328	205,525	9½
London, Brighton, and South Coast, ...	226	2,364,091	407,026	2,771,117	145	113,217	10½
London and South-Western, ...	456	3,113,898	1,297,899	4,411,797	177	144,742	7¾
South-Eastern, ...	286	2,300,500	691,217	2,991,717	189	123,783	9¾
Caledonian, ...	238	1,043,858	2,242,663	3,286,521	224	109,665	8
Manchester, Sheffield, &c., ...	179	1,296,008	1,375,810	2,655,738	133	96,861	8¾

latter undertaking, although virtually merged in the Great Northern, unfortunately mixed up the outlay incurred in the re-

pair of carriages and trucks with the locomotive expenses, at any rate in the return from which our table is compiled."

Upon the same subject another useful table of comparative locomotive expenses is given by the "American Railway Times," the comparison being between the Illinois Central Railroad and the Midland Railway, running from Leeds to Derby, and including the branches to Birmingham and Rugby.

Performance of Locomotives on the Illinois Central Railroad and the Midland Railway for Five Years.

ILLINOIS CENTRAL RAILROAD.

Years.	Total Miles.	Wages of engineers and firemen.	Cost of oil, waste, and tallow.	Cost of fuel.	Cost of repairs and materials.	Cost of cleaning.	Total cost.
		dols. cts.	dols. cts.	dols. cts.	dols. cts.	dols. cts.	dols. cts.
1858	1,998,144	79,447 71	18,288 93	180,233 17	102,592 27	15,434 87	395,996 95
1859	2,142,864	81,824 43	16,328 80	222,236 67	111,747 23	13,363 21	445,500 84
1860	2,437,822	96,623 77	19,160 31	212,009 67	148,502 47	15,477 2	491,773 24
1861	2,458,023	94,414 19	17,865 46	184,122 47	154,702 64	14,037 64	465,142 40
1862	2,551,192	98,484 51	17,113 84	156,141 45	159,588 54	14,797 48	446,125 82
	11,598,045	450,794 61	88,757 34	954,753 43	677,133 15	73,110 22	2,214,538 75

Years.	Cost of wages, per mile.	Cost of oil, &c., per mile.	Cost of fuel per mile.	Cost of repairs per mile.	Cost of cleaning per mile.	Total cost per mile.
	cts.	cts.	cts.	cts.	cts.	cts.
1858	3·97	0·91	9·02	5·13	0·77	19·81
1859	3·81	0·76	10·37	5·21	0·63	20·78
1860	3·96	0·78	8·70	6·10	0·63	20·17
1861	3·84	0·72	7·49	6·29	0·57	18·92
1862	3·85	0·67	6·10	6·23	0·57	17·42
	average 3·89	average 0·76	average 8·23	average 5·84	average 0·63	avera. 19·35

MIDLAND RAILWAY.

Years.	Total miles.	Wages of engineers and firemen.	Cost of oil, waste, and tallow.	Cost of fuel.	Cost of repairs and materials.	Cost of cleaning.	Total cost.
1856	7,431,799	£41,437	£12,677	£94,737	£122,470	£15,089	£286,410
1857	7,819,549	42,085	12,503	91,475	124,221	15,304	285,588
1858	7,912,498	41,929	10,639	88,091	117,805	15,162	273,626
1859	8,541,455	43,986	11,166	78,147	125,530	19,080	274,910
1860	9,606,612	48,843	14,155	74,844	149,831	17,055	304,728
	41,311,913	£218,281	£61,140	£427,294	£639,857	£78,090	£1,425,262
Years.	Cost of wages per mile.	Cost of oil, &c., per mile.	Cost of fuel per mile.	Cost of repairs per mile.	Cost of cleaning per mile.	Total cost per mile.	
1856	cts. 2.68	cts. 0.82	cts. 6.12	cts. 7.90	cts. 18.50	cts. 18.50	
1857	2.58	0.76	5.62	7.62	0.94	17.50	
1858	2.54	0.64	5.34	7.14	0.92	16.60	
1859	2.48	0.62	4.40	7.06	0.90	15.44	
1860	2.44	0.70	3.74	7.48	0.86	15.22	
	average 2.54	average 0.72	average 4.96	average 7.44	average 0.92	average 16.56	

" In the statement of operations of the Midland Railway from which the above figures are derived, the cost of cleaning includes the wages of 'cokemen and labourers:' in that of the Illinois Central, the cost of fuel includes all handling and putting it into the tender: the wages of labourers employed in the shops, or in

handling material, is included in 'repairs.' On the Midland, one half of 'salaries and printing' is included in 'repairs;' on the Illinois Central, nearly all of 'salaries' is included in 'repairs,' but printing is charged to another account. On the Illinois Central, the passenger and through freight engines are not allowed any mileage for switching or for standing with steam up: on English roads an allowance of six miles is made for every hour an engine is under steam and not in actual service. Bringing the Illinois Central mileage to this system, the total miles run would probably be increased five per cent.; which would make the total miles for five years 12,177,947, and the total cost per mile 18.43 cents. In reducing the mileage expenses of the Midland Railway to cents, one penny is assumed as equal to two cents."

We proceed now to the consideration of road locomotives and traction engines. The problem of a serviceable and efficient traction engine is still one which, comparatively speaking, remains unsolved. The great obstacles to be overcome by the roughness of the road render the employment of steam power a matter of difficulty and doubtful economy. The locomotives act of 1861 has also thrown many difficulties in the way of the maker—in specifying the form and breadth of wheel. It will be well, therefore, if we notice here a few of the provisions of this act as given by the '*Engineer*:'—

"Any carriage containing within itself the means of its own propulsion, pays the same turnpike tolls for every two tons of its weight, or fraction of two tons beyond any even number of tons, as is levied on a single horse and cart, the latter having wheels of the same width as those of the engine. In the case of engines of the Boydell class, the width of the shoes is to be taken as the width of the wheels. For every carriage drawn or propelled by a road locomotive, the same toll is payable for each pair of wheels as is paid by two horses drawing a cart, &c., with wheels of the same width, and for every single wheel beyond a pair or pairs, half of this toll is to be paid. In other words, for each wheel of every carriage drawn or propelled by a road engine, the same tolls are to be paid as for one horse drawing a vehicle having wheels of the same width. If, however, the wheels of the carriages drawn by an engine are not cylindrical, one half more toll is to be paid.

None of these provisions apply to private roads or bridges, nor to the Commercial Road. Engine-drawn carts not having cylindrical wheels must not carry a greater load than is allowed by the general turnpike Act. Where the wheels are cylindrical, not over $1\frac{1}{2}$ tons may be carried on a pair of wheels of a carriage drawn by an engine, unless the wheels are 4in. or more wide. If 6in. or more wide each pair of wheels may carry 2 tons; if 8in. or more wide, each pair may carry 3 tons, but in no case, with the following exceptions, is each single wheel to carry more than two tons, including the weight of the carriage itself. The exceptions are for carriages with springs, which may carry one-sixth more than the above-mentioned weights, and no restriction of weight is to be imposed in the case of vehicles loaded with a single tree, block of stone, casting, forging, boiler, or other object which, whether in a single piece or in two or more united together, forms one whole.

"Either of her Majesty's principal Secretaries of State may prohibit the use of any road engine which he may consider dangerous or hurtful. Such prohibition is to be published in the *Gazette*, and if disregarded a penalty not exceeding £10 may be enforced.

"No engine weighing more than 15 tons is to be taken over a county bridge, nor over a parish bridge when the weight exceeds 12 tons. The owners of such engines are answerable for all injury occasioned by them to bridges.

"Road engines must not emit smoke, under a penalty of 40s. for every day of the continuance of the nuisance.

"Every road engine must be attended by two persons, and if two or more vehicles are drawn another attendant must accompany them. Two good lights must be provided for night work, and these are to be lighted one hour after sunset and kept burning until one hour before sunrise, whenever the engine is employed on a highway between those hours. The penalty for neglect is not to exceed £5.

"Engines drawing agricultural machinery are exempt from highway tolls.

"No engine must run upon a highway at a speed exceeding 10 miles an hour, nor within a city, town, or village at a speed exceeding 5 miles an hour. The penalty for infraction

of this restriction is not to exceed £10 in the case of the owner, nor £5 in the case of the person working the engine not being the owner.

"No locomotive exceeding 7 ft. in width, nor, where the weight exceeds 3 tons, with wheels less than 6 in. wide, may be driven within the city of London without permission of the Lord Mayor, nor elsewhere in the metropolis without permission of the Metropolitan Board of Works, nor in any municipal or parliamentary borough without permission from the proper authority. The penalty for neglect is not to exceed £5 per day of such unauthorised use.

"The weight of every road engine must be legibly marked upon it, under a penalty not exceeding £5, while the exhibition of a false statement of the weight involves a penalty not exceeding £10."

The 3d clause of this act also provides, that every locomotive drawing a waggon or carriage shall have a breadth of not less than 9 inches, and the wheels of every locomotive shall be cylindrical or smooth-soled, under a penalty of £5 for every day any engine infringing such act shall be at work. Such a clause as this, of course, limits the maker to the use of smooth wheels, and therefore compels him to have them nearer 18 inches than 9 to secure the necessary adhesion. On the subject of the construction of such engines, the '*Engineer*' says—

"We have always the fact to deal with, that on a level pavement the resistance to the motion of a carriage is from 25 lb. to 35 lb. per ton, and that on ordinary roads the resistance is from 75 lb. to 150 lb. per ton. This is exclusive of gravity or inclines, and which, on the steepest part of Holborn hill, for example, would be 160 lb. per ton, and, on inclines of 1 in 50, nearly 45 lb. per ton. If a tractive power of say 150 lb. be provided for every ton of the weight of the engine, a 5 ton engine would have 750 lb. of tractive power, and at 10 miles an hour would have to exert 20 actual horse-power. This power would doubtless take a 5 ton carriage at the rate of 18 miles or 20 miles an hour over a good road, with resistances not exceeding in all 75 lb. per ton. As to the power which may be obtained in a steam carriage of a given weight we have the example of *steam fire-engines*, in which, with a weight of 3 tons, a power

of from 40 to 50 horses is often exerted. With traction engines, however, of 10 tons weight, we believe 50 indicated horse-power is about the utmost exerted. There are reasons, of course, why a traction engine, or even a steam carriage, should weigh more than a steam fire-engine of the same horse power, yet the actual difference appears to be greater than it ought. We do not know the weight of Bray's engine, but presume it is not far from 12 tons. It is said to have exerted a draught of 9,000 lb., at a speed of $1\frac{1}{2}$ mile an hour, over and above its own resistance. The useful effort would be 36 horse-power, and the total work, including the resistance of the engine, say 50 actual horse-power. It is well known that, with a load of nearly 40 tons, any traction engine of 12 tons' weight would be considered to be heavily worked, yet on even but a moderately fair road the work done at $2\frac{1}{2}$ miles an hour would not exceed 20 horse-power; and if horses were actually employed, it is clear that each might be counted equal to a load, including waggon, of at least $2\frac{1}{2}$ tons. We have seen one of Aveling's engines, said to weigh 10 tons, take two loaded trucks, weighing 10 tons, up an incline of 1 in 7 at the rate of about 2 miles an hour. Here the total resistance would be about $3\frac{1}{2}$ tons, and the horse-power rather more than 40. The engine, however, could have taken a larger load. A railway locomotive and tender of five times the weight would have exerted ten times the power, and a steam fire-engine of one-fourth the weight, or $2\frac{1}{2}$ tons, would have exerted an equal power (40 horses).

"It is indispensable in the case of geared traction engines, intended to move very heavy weights, that the engine should be heavy in order to obtain adhesion; or otherwise, as in the case of Messrs. Chaplin and Co.'s traction engine, that the load should rest on the framing of the engine itself. The feathering spades in the wheels of Bray's engines, and the clips and studs employed in the wheels of other engines, are for the purpose of obtaining a stronger 'bite' on the ground. It cannot, therefore, be considered an object to greatly diminish the weight of traction engines, but in the case of steam carriages, intended only to move themselves, and from 10 cwt. to even one ton of passengers, or perhaps one-half the number carried in an ordinary omnibus, we think the weight should not greatly exceed

that of steam fire-engines working up to 40 horse-power. Vertical boilers with small tubes, as used in fire-engines, are lighter and involve less weight incidentally in the way of framing and fastening than the ordinary horizontal boiler. The employment of double cylinders is, in our opinion, attended with an increase of parts, complication and weight, without a single attendant advantage. We are referring, at present, only to steam engines for common roads, although single cylinders answer every purpose for many other classes of engines. For steam carriages for the conveyance of passengers we believe, too, that gearing is wholly unnecessary, and that a single cylinder connected to an intermediate shaft, which, in its turn, is connected by coupling rods to a crank axle, is preferable to any other arrangement. In steam passenger carriages there will be at least 250 lb. adhesion of the driving wheels for every ton of the weight upon them, and if two-thirds or even three-fifths of the whole weight is on the driving wheels, there should be no danger of slipping, unless the engine is geared down to a very slow rate.

"Thus far we have seen few, if any, features of steam fire-engine practice introduced into steam carriage construction. We cannot believe that steam carriages will ever give satisfactory results until the present style of construction is much modified. And many of the same changes may be profitably made in traction engines. One of the most successful 10 ton traction engines now in use costs but £420, while others with costly wheels, double cylinders, and other appendages of doubtful value, cost from £1,100 to £1,750. Before steam can be successfully introduced upon common roads its application must be simplified to the last degree of possibility."

The manufacture of the wheels is an important matter also. The usual method is to make the boss and rim with tyre of cast-iron, the tyre being channelled longitudinally and transversely, also "chilled in casting;" others, however, and the most improved, such as in Fowler's ploughing engine, are made of wrought-iron boiler plate, 16 in. broad and $\frac{3}{8}$ in thick, the spokes being secured to such rim by two rings of T-iron riveted to each edge, the spokes crossing from the inner edge of the boss to the outer edge of the rim, and *vice versa*, they being cast into the boss,

We have seen other wheels having similarly plain soles, and the spokes made of wrought-iron gas tubing; such wheels were 18 inches broad, and, with a few of the rivet heads projecting round their peripheries, no slipping was experienced with the heaviest loads. So far as the act goes, we do not think such act precludes the use of small rivet heads, and even if it did, we know that a rough boiler plate tyre 18 in. broad, running over an ordinary road, will secure all the adhesion required in ordinary engines of say 8 to 10 tons weight. The '*Mechanics' Magazine*,' which finds much fault with the act, and which makes the most of rough wheels, says—

"We have already stated that the tyres of such wheels are thin; and overhanging the spokes, as they do at each side, from their great breadth, it is obvious that a few days' use would render them polygonal rather than circular, as the rim would flatten between the spokes; in order to avoid this, strengthening pieces, or 'strokes,' as they are termed, are fixed round the outside of the tyre proper. The general arrangement of these strokes is a point on which much difference of opinion exists; the best practice places them in two rows, side by side, round the wheel; they are made in lengths, generally of about 2 ft., and from 3 to 5 in. wide, and are of course firmly riveted together on the tyre. Not only do these strokes then strengthen the tyre, but they also serve the scarcely less important purpose of protecting it from wear; they are themselves easily replaced when worn out, while replacing a tyre is rather a serious undertaking. The general practice is to leave a space of about 3 in. between the ends of these strokes, such spaces proving of the utmost value in retaining the clips or spades put on when the traction engine has to cross turf, which smooth wheels can hardly accomplish.

"Now it is scarcely possible to construct a suitable wheel, lighter or more cheaply than the one to which we refer, but the Locomotive Act renders the use of such a wheel absolutely impossible, if the law be vigorously enforced, unless the proprietor feels disposed to pay £5 a-day for the privilege; and the worst and most injurious characteristic of the clause is, that it will accept no equivalent for the 9 in. of smooth sole. In one of Hogarth's pictures, we see an electioneering party bearing a ban-

ner with the inscription, 'Give us our eleven days;' the authors of Vic. 25, cap., exclaim, with equal pertinacity, 'Give us our 9 in. ;' it will not suffice that we may have even double the area of tyre surface resting on the ground at one time. According to the framers of the bill, two $7\frac{1}{2}$ in. tyres are far more injurious to the road than one 9 in. with a double load; and the effect of this is, that as a single 9 in. stroke will not effectually protect a 12 in. tyre. Besides greatly increasing the first cost of construction, builders of this class of engine must either submit to have cast-iron tyres, or use wrought ones of great thickness, costing about three times as much as would otherwise be necessary.

"We have no doubt that the framers of the clause intended to prevent injury to the roads. They may feel surprised when we inform them, that there is nothing so likely to injure a road as a smooth wheel; its capabilities for doing mischief far exceed that of the rough wheel in general work; the reason is obvious enough. The only injury a traction wheel can do to a road, apart from that common to the rolling action of all wheels, is by slipping. It is evident enough that so long as a tyre is so moderately loaded in proportion to its bearing surface, that it does not sink into the road, that its rolling action can do comparatively no harm; but so soon as such a wheel begins to slip, it will cut, or rather grind away the road.

"It is quite as much the wish of the engineers to avoid this slipping as it is the desire of the legislature to prevent the consequent injury to the roads; but instead of permitting the use of a rough surface, to prevent this slipping, and consequent abrasion, the latter compels the former to resort to a smooth wheel, which exerts an attracting action almost continuously. Be it remembered, that we do not for a moment advocate the use of spikes, spades, &c., on our highways; such means of obtaining adhesion are, except in a very few cases, not only unnecessary, but positively inapplicable, whatever theorists, who are only acquainted with the road locomotive on paper, may imagine. Half-a-dozen semi-spherical steel rivet-heads projecting half or three-quarters of an inch from each square foot of the tyre, will give an ample amount of adhesion for all ordinary purposes; *wheels so provided, 12 in. wide, and each loaded with 3 tons, possess quite sufficient adhesion to draw 20 tons up an incline*

of 1 in 15 or 20 without slipping, and will injure the road so little that they will scarcely leave a mark to show where they have gone; it has been urged that the use of all such projections must dig up the road on the same principle as the rotary digging machine; such an assertion is simply absurd; did the wheels slip they would certainly injure the road more than a smooth wheel, but such roughness effectually prevents slipping; and so long as a wheel with projections of such moderate length continues to roll, it can do little injury; indeed, we must recollect that the road is not smooth; on the contrary, every part of it is rough, and full of inequalities; and into these hollows and inequalities, such projections as we speak of fit without necessarily injuring the road in the slightest degree.

"We do not pretend to assert that traction engines are absolutely harmless; we do not wish to maintain, with some, that they actually improve a road; but we maintain that, for the transportation of heavy goods, at moderate speed, they exert a far less injurious action; it is easy to see that a cavalcade of fifteen or twenty horses with spiked shoes must do more damage to a road than a broad wheeled traction engine transporting the same load, the projections on whose tyres need not be greater than those on the horses' shoes. So far from digging up the road, these projections make but a slight indentation; with a properly smooth wheel the case is different; such wheels slip almost continuously, and being always as heavily loaded as possible, in the attempt to obtain adhesion, woe to the road on which they are at work. We have seen a furrow ten yards long left by such a wheel, where a rough one would scarcely have marked the place where it passed.

"We thus see that this clause is calculated to defeat the end it had in view by its framers, and that it bears so injuriously on the construction of this class of engine that it amounts almost to a prohibition of their use, and prevents in consequence the further development of a principle likely to add very extensively to our sources of transit. We believe that the matter only requires to be placed before the public in its proper light, to obtain such a readjustment of the existing law as will prove satisfactory to all parties."

In concluding this subject we cannot do better than give the

following accurate description of one of the most successful traction-engines, Messrs. Aveling and Porter's, yet constructed. The '*Mechanics' Magazine*,' from which we extract it, after some preliminary remarks on the state of roads, &c., goes on to say,—

"The traction-engine that was perhaps the most admired by good judges for its combined simplicity and efficiency, and for its low prime cost, the usual accompaniment of simplicity, was the 'exhibit' of Mr. Aveling, of Rochester. Its construction was a happy marriage of ingenuity with common sense. A nearly identical engine to the one in the Exhibition was also at work at the Battersea Agricultural Show of last year. The engine in the Exhibition weighed 8 tons empty, and about 10 tons when full. The cylinder was 10 inches in diameter, and 12-inch stroke. The fire-box was of Bowling iron, with stay-bolts pitched 5 inches from centre to centre. The boiler was flush from end to end. A pair of longitudinal stays placed below the tubes were made to connect the two tube plates. The fire-box was lagged, and the engine was counter-weighted. The driving wheels could be easily disconnected from each other, and from the propelling gear, by taking out a pin uniting the boss of the wheel with another boss on the axle; this is for easily turning round corners. There was a powerful friction break on the driving axle, in case of need when descending an incline. There was no steam dome, properly so called, on the boiler, but the cylinder was surrounded by a lagged metal jacket. This steam chamber is brought into direct communication with the steam by means of holes made in the top of the boiler, the cylinder being bolted thereon. The steam thus circulates constantly round the cylinder, and there is no necessity for a steam pipe. The cylinder being placed close up to the chimney, the exhaust pipe is thereby very short, with its attending advantage of a small back pressure.

"There will be little tendency to prime in this engine, as the cylinder is placed as far as possible from the fire-box, the place where the water is most agitated by the ebullition; the steam is dried by the dome-like properties of the peculiar construction of cylinder; and on ascending inclines, the cylinder is necessarily fed with dry steam. The steering apparatus is very simple; it consists of a single steering and carrying wheel, made to swivel

on its supporting rod at the end of a light wrought-iron frame fitted to the front end of the smoke-box. A man sits in front of the engine, guiding the wheel in his hand, and the massive traction-engine behind is literally 'led by the nose' by means of this simple steering gear. The self-propelling gear consists of a pinion on a feather at the end of the crank-axle, and working into a larger wheel on a stud below; on this wheel is cast a pinion with chilled teeth, to take in a pitch chain, made of massive iron links and steel pins. In the bracket carrying the axis of the drum, there is a curved slot in which the block for the stud of the small chain wheel can be made to slide. The curve of this slot is struck from the centre of the main driving-shaft above. The spur wheel thus always remains in gear with the driving pinion on the crank shaft. These were some of the peculiarities of the engine in the Exhibition. One of its most important features was the excellent construction of fire-box and boiler, enabling it to raise the high pressure of steam for exerting the great power required from a traction-engine.

"By the courtesy of Mr. Aveling, we were lately enabled to see the performance of one of his peculiar traction-engines. The engine tried was one of the several now being manufactured at the Rochester Works for the Yudanamutana Copper and Mining Company, South Australia. The mines of the company are about 120 miles from Port Royal, and the ore has to be transported all this distance over an unbeaten tract of ground. The traction-engines have to run ten miles at a stretch; there being water stations at every tenth mile. We believe that Messrs. Aveling and Porter are also making the fixed plant for the stations. The cost of carriage is said to be nearly £10 per ton, but as the fuel (wood) is cheap and plentiful, the traction-engines will probably reduce the freight to £2 per ton. In its main features the engine was similar to the one in the Exhibition, but it embodied several improvements and additions. The engine tried weighs, empty, 11 tons, and about 13 tons in working trim. The fire-box is 40 in. long, 31 in. wide, and 20 in. deep inside. The fire-box stay bolts are $4\frac{1}{2}$ in. from centre to centre. The boiler is 3 ft. 1 in. in diameter inside, containing 37 lap welded tubes, $2\frac{3}{4}$ in. in diameter outside, and 5 ft. 7 in. long; the barrel and outer fire-box being of $\frac{3}{8}$ plates, from Earl Dudley's Works;

the inside fire-box is of the same thickness of plate; the fire-box tube plate and the door plate are $\frac{1}{2}$ in. thick. The smoke-box tube plate is a round disc $\frac{5}{8}$ thick, riveted within the smoke-box; being flanged all round. The barrel of the boiler has butt-riveted joints and straps, and there are two longitudinal stays in the boiler barrel. The whole boiler is flush, and without any angle iron. The fire-box is carefully lagged. The construction of the entire boiler seems to come up to the best standard of locomotive work, and is thus enabled to use the locomotive steam pressures of 100 to 120 lbs. in the square inch. The cylinder is 10 in. diameter and 12 in. stroke, like the cylinder of the Exhibition engine; it is cast from the same pattern, and arranged on a similar plan. On investigation, no inconvenience appeared to arise from there being only one cylinder, as the driver could easily take the engine off the dead points by turning the multiplying gearing at the other end. The steering gear is also the same. The working parts are neatly housed in from the influence of the weather. The toothed gearing was also covered with light cast-iron splashers. The chief differences between this engine and the one in the Exhibition consist in the mode of taking up the slack chain, and in the gearing being double, in order to get either two miles or four miles an hour speed of traction-engine.

"There is a pinion at each end of the crank shaft; and either of these pinions can be thrown in and out of gear with the spur wheel below by sliding it along a feather on the shaft. The pinions are ingeniously kept in the positions required by means of a simple clip or spring steel, embracing the shaft, and lined with leather; it is quickly slipped off and on the shaft as required. The ratio of gearing obtained by the pinions and plate wheels is 1 to 20 on one side and 1 to 14 on the other. As in the Exhibition engine, the brass bearing carrying the large toothed wheel is fitted in a radial slot struck from the centre of the crank shaft. The adjustment for taking up the slackness of the chain is, however, effected in a different manner. The brass bearing is kept up in the slot by a block at bottom. There is another cast-iron block above, lying on the bearing and kept down by a set-screw. When the bulk of the chain has to be taken up, the thinner block below is taken out, and the thicker one above is substituted *in its stead*. The brass step is thus fixed in a perfectly firm and *solid adjustable bearing*. A neat plate covers up the whole.

"The driving wheels are 6 ft. 6 in. in diameter, with a cast-iron rim, 18 in. wide, and a cast-iron nave 15 in. diameter. There are fourteen wrought-iron spokes, $2\frac{1}{2}$ by 1 in., cast $3\frac{1}{2}$ in. into the nave, the ends of the spokes being first notched and dipped into tar. The nave is cast one day after the rim, so that the contraction of the rim may not affect the strength of the wheel. The driving wheels of the Exhibition engine had blank spaces on the face, in order to slip **T** iron paddles or clips on to the wheels when passing over soft and yielding ground. In order to conform with the Locomotives Act, these openings are now filled up with small castings, dove-tailed in, and further fastened by pins. These castings are slipped off, when it is wished to put in the **T** iron clips. Spikes are also employed to increase the grip of the wheels. The bearings are inside the wheels. The driving axle is of scrap iron, 5 in. in diameter. The axle is fitted in axle plates fixed outside the fire-box, between the latter and the tank behind. Thus, although there is no longitudinal framing, the traction strain on the fire-box is, in a great measure, taken up by the intermediate grip of the wheels on the ground.

"The weight is chiefly on the wheels, particularly on steep hills, which somewhat accounts for the remarkable performances of this engine. There are no springs, Mr. Aveling not judging them necessary for the slow speeds at which the engine is intended to work—from two to four miles an hour. There is a blower in the smoke-box. The man-hole is in the smoke-box tube plate. There is a warming cock for heating the water in the tank. The *lower* slide bars are of steel. The chimney is of cast-iron, in one casting $\frac{1}{4}$ in. thick. The ends, top and bottom, of the water-tank are made of cast flanged plates, the wrought-iron sides being bolted directly thereto. The water-tank in front of the fire-box contains 69 gallons of water; the tank behind contains 211 gallons. The tanks carry coal and water for a run of 10 miles. We saw 'No. 53' marked on the Yudanamutana engine, which evinces great success in the sale of traction-engines, as we believe that the firm took up this branch of their business only three years ago. The price marked on the engine in the Exhibition was £420. On account of the one tried being made with a larger fire-box, double gearing, additional water-tank, &c., *this price has been raised to £530.*

"The traction-engines now making for South Australia are intended to draw a train of about six waggons. Each waggon is strongly built of oak, and is on four wheels, the front wheels being 3 ft. 6 in., the hind wheels 4 ft. 9 in., in diameter. The front wheels can swivel, and there is a light iron coupling between each waggon. At the late trial of this traction-engine the roads were in a yielding, sloppy state, from the effects of the weather; the mud formed a complete lubricating material between the wheels of the engine and the road. At the same time, to prevent any injury to the road-surface, the clips were not applied to the driving wheels; a few spikes only were inserted in the rims. Each waggon, when loaded with large baulks of timber, weighed about five tons. We saw the engine take five waggons up inclines varying from 1 in 12 to 1 in 8, at speeds varying from four miles to about two miles an hour. The engine ran 7 miles in about $2\frac{1}{2}$ hours, and consumed about 3 cwt. of coal. Probably, no traction-engine, of the same weight, has ever accomplished so much. The engine, with its train of four coupled waggons, passed some very sharp corners with great ease. This is one of the great advantages of an engine over a train of horses, as in turning corners only one or two horses are able to pull properly. The hissing of the steam certainly frightened some horses on the road. This is one of the impediments to the more general introduction of traction-engines. We know, however, by our own experience, that horses very soon get accustomed to the whistling of steam.

"It is well known that the resistance offered by the surface of a common road to the motion of a vehicle is in a direct ratio to the load; is in an inverse ratio to the diameter of the wheels; while the resistance is almost uninfluenced by the breadth of the wheels. At slow speeds the resistance is almost independent of the velocity of the vehicle. The co-efficient of resistance, however, varies so much with the state of the road (according to Morin, about from 1-13th to about 1-50th of the load), that it would be scarcely possible to estimate, by calculation, the precise tractive power exerted by Mr. Aveling's engine. Suppose we compare the traction-engine to a team of horses; neglecting the power exerted in moving itself, and only taking into account the four loaded cars. Each car weighed with its load about 5 tons, with wheels averaging 4 ft. in diameter, and $4\frac{1}{2}$ in. in tyres. Considering the bad

state of the surface, we may take the co-efficient of resistance on the road at 1-20th of the weight; and the four cars weighing together 20 tons, the resistance on a dead level would thus be 1 ton. To this would be added 2 tons for an incline of 1 in 10, making a total of 3 tons for four waggons, on an incline of 1-10th.

"Perhaps the most accurate means of learning the available tractive power would be to use a strong dynamometer, similar to the one employed by Mr. Fowler for ascertaining the draught of his six-furrow steam-plough.

"We believe that we may congratulate both Mr. Aveling and his customers on the results of the experiments we lately witnessed."

It may be probably as well to append to this section the following account of the trial of portable engines which took place last year at Worcester Royal Agricultural Show.

The prizes offered by this society were for fixed engines not exceeding 12 horse-power, £40, and £10 for the boilers of such engines. For portable engines £25 not exceeding 8 horse-power, and £25 for those exceeding 8 horse-power. The nature of the tests were as follows, and were instituted principally with a view to determine the quantity of fuel consumed. The judges were, Daniel Kinnear Clark, Esq., C. E., author of the well known work on Railway Machinery; G. V. Gooch, Esq., C. E.; and Mr. Stewart of the Midland Railway.

The portable and fixed engines were arranged on the ground, and the former had 7 lbs. of coal and 1 lb. of wood per horse-power, carefully served out to them; the fire being then lighted and steam got up to a pressure of 50 lbs. per square inch: the whole of the coal in the fire-box was then taken and weighed, the weight being deducted from what was served out at first, so as to enable a correct estimate to be formed of the amount required to raise steam. The driving-wheel was then placed in connection with the pulley of the friction dynamometer (which was made by Messrs. Easton, Amos, being an improved form of De Prony's friction brake) by means of a leather belt. The engine, thus arranged, is now required to exert its force upon the Dynamometer, whose number of revolutions are registered by a counter, and is allowed to run as long as it will turn the brake at the required speed. When the engine is stopped a second portion

of fuel is served out, when steam is again raised to 50 lbs. per sq. in. Every means are employed in stoking to keep up steam as long as possible, and the fuel is broken up into small pieces, not larger than a small hen's egg.

When the engine has exhausted its power a second time, the number of revolutions of the brake are noted. The speed of the brake is obtained by the relative proportions of its pulley and the driving wheel of the engine, the number of revolutions of the latter being known. The load on the brake or engine is determined by the nominal power of the engine multiplied by 33,000 and divided by the circumference of the centre of effect of the *brake proper* or collar, multiplied by the number of revolutions of the brake wheel per minute. The duty of the engine is obtained by dividing the total number of revolutions of the brake wheel by the number of revolutions of the engine per minute. The conditions of the engines competing were very numerous, the most important were: Of the portable engines it was required that the 8 horse class should not exceed that power, nor have a cylinder of greater diameter than $9\frac{3}{4}$ in. No fixed engine should exceed 10 horse nominal power, nor have a cylinder exceeding $11\frac{1}{2}$ in. The engines were required to be submitted either before or after trial to a complete examination of their valves, pistons, and other internal fittings, so that convenience of arrangement might be considered by the judges along with the working efficiency. The tubes in boilers were not allowed to be smaller than $2\frac{1}{2}$ in. inside nor less than No. 12 W. G. thick, the tubes to be spaced not closer than 1 in. clear.

The following table exhibits the results of such trials:—

FIXED STEAM ENGINES.

Name of Exhibitor.	Catalogue No. of Article.	Horse Power of Engine.	Coal burnt per Hour in lbs.	Coal burnt per Horse Power per Hour, in lbs.	Price.	Remarks.
Barrett, Exhall, and Andrews	2537	10	48.8	4.88	£230	Prize of £15.
Clayton and Shuttleworth....	141	10	50.4	5.04	240	Ditto of £15.
Hornsby and Sons.....	1945	10	55.1	5.51	245	Ditto of £10.
Ferrabee	3373	10	71.0	7.10	230	Commended.
Tuxford and Sons	5014	8	56.5	7.06	200	
Haywood, jun.....	548	10	87.7	8.77	240	
Johnson and Whittaker.....	2867	4	61.3	15.32	85	

PORTABLE STEAM ENGINES.

Name of Exhibitor.	Catalogue No. of Article.	Horse Power.	GETTING UP STEAM.				Coal burnt in lbs. per hour.	Coal burnt per horse power, per hour.	Price of Engine.	Remarks.
			Time taken in getting up Steam.	Fuel burnt in getting up Steam.		Wood.				
				Coal.	lb.					
TABLE I.										
Hornsbly and Sons.....	1946	12	48	62.0	12	lb.	45.5	3.79	325	Prize of £10.
Clayton and Shuttleworth.....	142	12	99	47.0	12		46.3	3.86	343	Do. of £7.
Tuxford and Sons.....	5004	12	69	60.5	12		55.2	4.60	355	Do. of £4.
Barrett, Exhall, and Andrews.....	2539	12	123	67.0	12		55.8	4.65	310	Do. of £4.
Brown and May.....	5774	10	78	47.3	10		54.5	5.45	265	Commended.
TABLE II.										
Tuxford and Sons.....	5003	8	81	32.5	8		28.7	3.59	250	Prize of £9.
Barrett, Exhall, and Andrews.....	2538	8	99	50.2	8		30.3	3.79	230	Do. of £8.
Clayton and Shuttleworth.....	143	8	100	38.2	8		32.4	4.05	238	Do. of £7.
Holmes and Sons.....	1824	8	41	39.0	8		46.5	5.81	240	Do. of £1.
Haywood, jun.....	549	8	76	41.0	8		44.1	5.51	240	Commended.
TABLE III.										
Ellis and Sons.....	4053	7	76	40.5	7		57.5	8.21	220	Commended as good serviceable engine.
Parsons.....	5246	8	63	34.0	8		70.6	8.82	225	Commended as good serviceable engine.
Warren (Ruston and Co.).....	3653	8	95	4.5	8		75.6	9.45	230	
Gibbons.....	519	7	49	.3	7		76.5	10.92	215	
Robey and Co.....	4827	8	47	.5	8		95.7	11.96	230	
A. B. Childs (Riches & Watts).....	5779	8	69	44.0	8		96.0	12.00	200	
Ashby and Co.....	5176	4½	73	5	4½		57.0	12.66	138	
Gilbert.....	1553	5	95	31.5	5		66.4	13.28	160	
Brown and May.....	5775	8	55	34.0	8		51.2	6.40	220	Highly commended.

As might be supposed, nearly the whole of the engines submitted for trial by the makers were specially constructed engines, in other words, were "racers." This was fully corroborated by most of the makers refusing to have their commercial engines

tried against such "racers;" some declaring that their other engines exhibited at their stands had no pistons. One firm only, we believe, consented to the trial, at least had no objections to consent; this was Messrs. Brown and May, whose engine, owing to some slight nonconformity in the tubes to the rules of the society, was disqualified for the prize list. This difference in the tubes (being outside measurement, we believe, in place of inside) gave the engine no advantage, although it nominally prevented them gaining a prize.

Many important improvements have been introduced in this department of engineering manufacture in the few past years; these, however, have been chiefly improvements of construction, no decidedly novel arrangements having been introduced. A considerable amount of locomotive practice, however, is becoming disseminated among the makers of portable engines; such practice illustrating itself in the shape of good boilers, well-stayed fire-boxes, and general good proportion of the working parts.

MARINE ENGINES.

Progress in this department of engineering has during the past few years been exceedingly slow; indeed, no decided advance has been made. Some attempts have been made to introduce superheaters, but without much success; in most cases the superheaters have become burned out, and in others it has been found that surcharged steam has a decidedly injurious effect upon the cylinders. A plan has been adopted of Wethered's to temper the surcharged steam with saturated or moist steam, so as to prevent its injurious effects upon the cylinder. This also has been abandoned. Surface condensation has been revived, and worked with a view to facilitate the adoption of high pressures ancillary to expansive working. In the engines the combined high and low pressure system seems to have made much progress, and this especially in the hands of the enterprising Glasgow engineers, Messrs. Randolph & Elder. Most of their engines are constructed on this their patented principle. The engines are usually of the inverted cylinder or hammer description, adapted for screw propulsion. The high-pressure cylinder is placed in a line with the low pressure cylinder, and at right angles to the crank-shaft. The low pressure cylinder has four times the area of the high pressure cylinder,

and is placed immediately over the centre of the crank-pin. The two cylinders are connected by an intermediate or side lever, so that while one piston ascends the other descends, and *vice versa*. The low-pressure cylinder is directly connected to the crank by the connecting-rod, and the high-pressure cylinder piston-rod is carried right down into the air-pump, which is placed in front of a surface-condenser. The two cylinders are jacketed with high pressure steam completely round and through both covers and ends. The boiler pressure is from 30 to 40 lbs. per square inch, the steam being admitted to the high-pressure cylinder, where it is cut off and expanded four to six fold; such engines have given good results, and have reduced the consumption of fuel to as low as 2 lbs. per indicated horse power per hour. They are, however, somewhat complicated engines.

Messrs. Humphrey and Tennant have recently patented some direct acting compound engines upon the combined high and low pressure principle. The small, or high-pressure cylinder, is placed in the same centre line with that of the low-pressure cylinder, into which the steam is exhausted. The low-pressure cylinder occupies a place immediately in front of the high-pressure cylinder, and communicates its motion through the medium of a trunk to the crank.

The general problem in marine engineering to be solved seems to be one of economy, not only in first cost, but in dead weight, as also economy of fuel, for this constitutes the greatest dead weight in ships bound for long voyages. The '*Engineer*,' speaking of marine engine economy, says, "The problem of marine engine improvement has not, however, been finally solved, and there are indications even that we shall have to retrace some of the steps already taken in this direction, at least should no timely remedy be discovered for some of the evils which have already appeared in connection with the reformed practice. In this we do not include the failure of high-pressure boilers, for steam of much more than 40 lb. has not yet been adopted to any considerable extent, although the attempt to introduce a pressure of 130 lb. in connection with surface condensation has already resulted in a large loss to one of the Mediterranean companies. It is certainly singular that, with distilled water, a high-pressure boiler has not yet been made to work properly at sea; but were we to describe

the extraordinary example of boiler-making employed in the attempt just referred to, there would be no wonder at the result. The failure was due, it would appear, to defective circulation, and to that alone. It is strange that the locomotive boiler, with the cylindrical fire-box of Mr. Allan, has not yet been tried at sea. This, we should anticipate, would answer well. Ramsden's high-pressure boiler is understood to have given good results, and considerable expectations have been raised by the description of Inglis' high-pressure marine boiler, which, we understand, is being tested in the north. Speaking of water circulation, it has been stated that the injector has been successfully employed upon some of the Woolwich boats to transfer the boiling water from one part of the boiler to another. It is alleged that boiling water may be readily forced by the injector if the source of supply be above the level of the instrument. In taking boiling water under pressure, the effect of the latter, as assisting in the movement, is to be considered. It has been denied, we should say, that the condensation of the steam passing through the injector is essential to its action; and it has been observed that, if the united jets of steam and water be directed into the open air, the steam disengages itself from the water at a short distance from the point of discharge, and rises by itself, to condense immediately in a visible cloud of mist. Some such result, indeed, was to have been expected, from the known large quantity of steam passed through the injector in performing any given amount of work. We introduce this subject, in connection with marine boilers, as it is possible that the injector may yet be found to serve other purposes than that for which, thus far, it has been almost exclusively employed.

"As for superheating, anything beyond drying the steam is found to introduce practical evils. But for these, possibly, superheating would have been long ago generally resorted to. In the old days of boilers working at or below atmospheric pressure, one Thomas Saint (specification No. 2,670, 1802) proposed to employ a self-acting valve, through which, whenever the steam fell below the atmospheric point, hot air might enter from the fire directly into the steam. In 1809 William English patented the application of superheaters to steam of about 227 deg. temperature, thereby expanding it so as to work with increased effect in

the cylinder of the engine. English proposed to use as a superheater a 'tube or tubes, or other appropriate vessels or receptacles,' his description pointing to iron tubes lined with brass or copper. He contemplated a red heat 'when required,' and this intensity of temperature, doubtless, proved the rock on which his scheme was wrecked more than half a century ago. He patented the use also of superheated steam for drying purposes, and the late Bryan Donkin took out a similar patent in 1816, and the same thing, we believe, has been several times patented since. Trevithick had heated his steam cylinders by means of a separate fire, and with good results as far as the mere economy of steam was concerned. The late Mr. Robert Stephenson stated on one occasion that it was from a communication from Trevithick that he was first led to place the cylinders of the Planet locomotive within the smoke-box. In the same year that this was done, viz., 1830, Dr. Haycraft took out a patent relating to superheating. His specification contained a blunder much the same in kind as that which Woolf committed when he declared, in 1804, that the steam of 40 lb. would expand forty-fold before falling to atmospheric pressure. Dr. Haycraft asserted that by superheating to 100 deg. above the normal temperature of steam it was expanded ten-fold, and the consumption of fuel for a given power diminished by nine-tenths. He, too, proposed to employ the cylinder as a superheater, by surrounding it with brickwork and applying fire to it. Surcharged steam, he stated, 'had heretofore been attempted to be used in steam engines, but without any success,' as it burnt up the lubricating material and destroyed the packing—exactly as it still does in our own practice. The Dr. proposed a contrivance, of no great probable merit, for preventing the evils of superheating, and he insisted upon the employment of metallic pistons instead of hemp packing. The most creditable feature in his specification was the employment of a small high-pressure boiler in addition to that working at low pressure, the steam from the former being passed through a steam jacket around the cylinder, and afterwards discharged through a small loaded valve into the low-pressure boiler. The Doctor particularly pointed out the object of preventing condensation within the cylinder, 'which condensation by the subsequent evaporation occasions an abstraction of heat and a conse-

quent waste of steam.' Most of his schemes anticipated a number of subsequent patentees.

"Superheating was not abandoned, nor did it, either, make much progress. In 1847, Moses Poole, in a specification, referred to the long experience of the loss of heat by condensation within the cylinder, and again proposed superheating. As the difficulties attending the use of very hot steam were well understood, Poole proposed to temper the heated steam with ordinary saturated steam, and with the help of a thermometer to maintain a workable temperature in the cylinder. This, of course, invalidated Wethered's subsequent patent for 'combined steam,' of which so much was heard five years ago. Since 1858 superheating has been resumed, and hot steam has been largely worked in marine engines in every part of the world. But in the case of the Holyhead and Kingstown boats, it has been found necessary to return to the old mode of working, with saturated steam, and although the iron tubes of superheaters have been generally made $\frac{1}{4}$ in. thick, the Peninsular and Oriental Company have found it necessary to abandon iron superheaters altogether, for the present, others of copper being employed in their new ships. In the practice of the leading engineers, Messrs. Penn, for example, a 'dryer' only is now employed. Steam, as it ordinarily escapes from boilers, generally carries more or less spray with it, and there can be no doubt of the advantage of completely converting this into good dry steam. Messrs. Fairbairn and Tait's experiments on the density of steam showed that, even where it was produced in small quantities, and with every care in the construction and management of the apparatus, it carried moisture away with it from the water. This was proved by superheating it, when it was found that the expansion for a few degrees above the point of saturation was three times more rapid than that which occurred at a higher temperature, under which the steam followed the usual law of gaseous bodies, expanding about $\frac{1}{81}$ th of its volume for each additional degree. To bring the steam wholly into the gaseous state, and even to heat it a little farther, is well enough; especially when we know that, without superheating, many engines are worked regularly without any other lubricant in the cylinder than that supplied by the condensed steam itself. As for the mode of superheating, it is not impro-

table that the best of any is that proposed by Haycraft; to wit, enveloping the cylinder with steam of a higher pressure than that worked within it, employing a small supplementary boiler for the purpose, as is now done on some of the Canadian steamers.

"As for surface condensation, it cannot be denied that a corrosive action has been manifested in boilers fitted with surface condensers, in some cases to such an extent that the boilers are rapidly destroyed. So, too, the brass or copper tubes of the condenser have been sometimes found to disintegrate to such an extent as to crumble to pieces within a short time. In America, where surface condensation has been extensively practised, some most striking, and, indeed, unaccountable, cases of this kind have been reported."

In writing of marine engine improvement, the '*Mechanics Magazine*,' comparing the marine engine with the locomotive, says,—

"Scarcely any class of engine has undergone the same amount of improvement as the locomotive; comparatively an infant in years, it shows all the science, culture, and physical development of the full-grown man. All the resources of science and the refinements of art have been lavished on it; always an attractive subject to mechanical minds, from its extreme beauty, its exquisite simplicity, and its vast concentration of power within the smallest limits, it has, perhaps, during the few years which have elapsed since the 'Rocket' first astonished those who gazed on its till then unparalleled performance, received more attention than almost any other form of engine; its powers of bringing itself before the public have been unrivalled, and, therefore, it has met with world-wide attention. Elaborate treatises have been written on the minutest points connected with its *physique*; its anatomy studied with a skill worthy of a Hunter, or a Cooper, and as a result we have—the modern locomotive, a machine before which admiration becomes dumb, and even praise sinks into silence."

"The great cause of locomotive improvement has been the free scope hitherto allowed, to both the builder and designer, for the free exercise of their respective talents; certain restrictions and limitations, so trifling as scarcely to merit the name, com-

plied with, they may follow the full bent of their inclinations, and introduce such alterations as their experience may suggest as likely to prove not only alterations, but improvements.

"In many cases we find, too, that, from the skill and attention of locomotive superintendents, particular classes of locomotives have derived certain peculiar advantages, which cause them to stand high in the opinions of the engineering public. Gifted, in most cases, with considerable attainments, and carefully trained in the practical routine of their professions, all such men required were the means and permission to carry out such experiments, and make such alterations as they considered would effect improvements. Directors willingly granted the permission, shareholders eagerly produced the pecuniary requirements necessary, and, as a consequence, locomotives of the most varied construction were turned out from the workshops all over the kingdom. Experiments could easily be entered into; no difficulty could possibly be experienced in trying a new engine, even although it was like nothing which had gone before, and involved the newest and strangest features; for risk was merely nominal, the cost of an engine seldom exceeding £2 000 or £3,000; so that, even if the machine proved an utter failure, and found its place in the scrap-heap instead of working the line, it was a matter of little consequence; no risk of life and limb, considerations far more important, being involved, it was just as safe to travel a hundred miles with such an engine as with one of the ordinary trains; indeed, we find that many of the most valuable results we possess have been obtained from experiments conducted with ordinary passenger trains in the usual course of business.

"Ranking before the locomotive in economy, though second to it in importance, we have the Cornish engine—a machine which approaches nearer to theoretical perfection than almost any other which man's ingenuity has enabled him to construct. Here, again, we see the result of genius untrammelled by conditions, either dictated by circumstances, or, worse still, by a lay public. The designer, totally unfettered, devotes all the energies of his well-trained mind to the subject, and regarding the machine in the abstract, instead of the positive, brings it to such *perfection that we find a consumption of a couple of pounds of*

coal per hour gives us a horse-power. How different in all respects is the history of the marine engine from either that of the locomotive or the Cornish; it is a history in which we find little but a constant war between theory and practice—a perpetual struggle, on the part of the engineer, to make that which was right expedient as well. The result has been a class of engines, heavy, bulky, and expensive, both to purchase and use, but possessing the one advantage, which, up to the present, at least, is considered to compensate for the want of every other, they are perfectly trustworthy.

“No improvement in the marine engine is likely to meet with universal, or even partial, adoption until it has been thoroughly proved by a series of experiments, conducted on a great scale, by able men; until, in fact, the engine has undergone the same thorough examination as the locomotive, we regret that at present we see little chance of any great undertaking of the kind likely to lead to useful results. It is true that, in a few cases, we see engines embracing many novel features taken into favour, but such cases are too rare to influence the public mind to any considerable extent. Experiments assume a very grave aspect indeed when they are performed on a machine costing tens of thousands of pounds, and on the successful working of which depends, it may be, the lives of hundreds of our fellow-creatures. The breaking down of an engine, the leakage of a boiler, has, ere now, alas, too often carried desolation and misery to many an English home; rash, indeed, would be the man who could for a moment advise such a departure from precedent as would introduce a single element of extra risk on board a steamship; hence we find old plans and models of engine adhered to with a tenacity of gripe which the hand of science has hitherto proved too weak to unloose. Let us ask ourselves, how long can this state of things continue; and, supposing we are dissatisfied with it, to what quarter are we to look for an initiative in a change for the better? These questions are doubtless full of importance, and worthy of the most serious consideration, not only from the engineer, but also from the public at large.

“The general practice amongst steam shipping owners is, when giving an order for an engine, to go to some first-class firm celebrated for the construction of the particular class of engine

they may require; and this firm would no more depart from the ordinary style of engine on which their reputation rests than they would bore holes in the vessel and send her to the bottom. Indeed, the certainty is that any attempt at the introduction of a decided novelty would be as stoutly resisted by the owners as the actual scuttling of the ship. With all our desire to see science advance, we cannot but admit that such principles are correct in the case of ocean steam-ships. Certain forms of engine a long series of years have proved trustworthy, and the loss of the ship and all hands, or even a considerable delay on her voyage, would be badly compensated for by the saving of a few tons of coals, or the use of a smaller engine. Such steamers are quite unsuited for the first embodiment of a crude idea—crude, because untried. Nor does the Navy offer a much better field. Such ships would badly fulfil their purpose did they break down far from home, perhaps close on an enemy's shore; but, fortunately for the ends of science, all necessary opportunities are still afforded to the engineer by the large class of vessels which carry on our home trade, making short voyages from port to port. Such vessels can rarely encounter any risk comparable with the ocean steamer, and often belonging to companies, who give almost unlimited powers to their manager, who stands, indeed, in nearly the same relation to his employers that the locomotive superintendent does to the board of directors. In such situations, men of talent and enterprise can do much; and, although tied up in many respects, they have nevertheless every reasonable opportunity for experiment; the ships with which they have to deal are generally of moderate size, and making but short voyages little danger is run of a breakdown, which is very unlikely to happen, because the ship spends so much time in port that every opportunity is afforded for the most thorough examination of the machinery.

But, granting that we have thus a sufficiently numerous class of steamers on which to conduct experiments, in what should these experiments consist? We reply, in the first place, that, on board a steamer, an engine on a perfectly new and untried principle should never be made the subject of experiment. We have known such cases where the only result obtained by a *really clever* thing was loss of money, risk of the ship and

crew, and the creation of such a disgust for anything new in the minds of all connected with the ship as led to the engine's being ignominiously removed, and replaced by machinery which could be depended on, although inferior in all other respects to that rejected. All such engines should be carefully tried on shore first, tried for many days in constant work ; carefully tried afterwards when on board the ship on the regular trial ground. Many things will be found to require alteration and improvement, and the result will most probably be a vessel which will give perfect satisfaction.

"In making use of the word 'experiment,' we do not mean the conducting of a series of observations in order to obtain certain information which we require relative to the working of any particular class of engine ; we mean that every engine the construction of which involves any novelty of principle or working detail, is in its first use an experiment, and requires careful testing ere the lives of passengers and the property of public companies are suffered to depend on its successful working.

"The question only remains, to what quarter should we look for success ? The answer is obvious ; no further economy can be obtained in steam power without the use of high pressure and expansion. The theorist who proposes such schemes may find fault, and complain of the tardy adoption of his ideas ; but he should remember the difficulties which beset the marine engineer in every attempt to make what is theoretically correct practically correct also ; that the possibility of doing so exists, is proved by the great comparative success which has already attended the labour of many of our junior firms ; and we feel little doubt that from such men the subject of steam propulsion will meet with such sound attention as must, in the course of a few years, lead to improvements which will make the marine rank with either the Cornish or locomotive engine in economy.

Again in another article it is stated, that "such engines as the 'Lord of the Isles' or the 'Great Britain' locomotives, have on many occasions exerted as much as 800 indicated horsepower, in regular work. If we neglect the weights of the leading and trailing wheels, springs, &c., as being only necessary to the locomotion of the machine, not to the mere exercise of its power, we shall find that any of them weigh considerably under

40 tons in working order—that is to say, with the boiler full and the drivers retained as fly-wheels. Now 40 tons divided into 800 horse-power, gives us 20 horse-power for each ton of dead weight. If we regard 800 horse-power as an abnormal effort, which, if long continued, might lead to the injury of the machine, and only consider the maximum of effect as 500 horse-power, we have still over 12 horse-power for each ton. Now, the best practice in marine engineering has hitherto failed to reduce the weight, of direct-acting engines, with tubular boilers and injection condensers, to less than 12 cwt. per horse-power nominal; and as the indicated generally exceeds the nominal, about three times on an average, we may safely say that a ton of the marine machinery in daily use produces but 6 horse-power, while a first-class locomotive can produce 12 or 15 with the greatest ease, and even 20 under exceptional circumstances; such facts speak for themselves, and ought naturally to lead to the consideration of the means of procuring equally good results in both cases: the first effect of which would be to place at our disposal a class of vessels possessing all the speed, and two or three times the cargo capacity, of the ‘Persia,’ for instance, without any increase in her size. Such vessels could not fail to prove more highly remunerative to their owners than anything which has gone before; and it is sufficiently remarkable that no trials have ever been made with steamships fitted with screw propellers and small engines of the locomotive class, running at locomotive speed with high-pressure. We can only attribute this supineness to the small interest which companies generally take in mere engineering concerns—matters which they usually trust wholly to their superintending engineer, who, having all the risk in case of failure, and but little prospect of reward in case of success, is commonly well satisfied to do well, without any desire to risk reputation or prospects in the attempt to do better. Nevertheless, the reward held out to shipowners is magnificent, and it is high time they bestirred themselves to obtain it.”

Much importance attaches itself to the manner in which marine engines are constructed, and this in particular to the fitting of brasses and bearings, &c. On this detail of the marine engine the ‘*Scientific American*’ makes the following practical remarks:—

"So little attention is given to this subject by persons who ought to know better, and so much indifference is manifested to the results of neglect, that we have felt it important to call attention to the subject, and, by pointing out the causes of disaster, bring the matter to the direct attention of all interested. Many steam engines have been disabled, and the safety of the passengers and cargo imperilled when on ship-board by inattention to the condition of the bearings. We have ourselves seen a large beam engine slowed down and finally stopped entirely from the cause alluded to—so hot had the beam centre (the part injured) become, that the utmost efforts of powerful men and a large sledge weighing some twenty pounds were unavailing to slack off the nuts which held the 'binder' down. As for unscrewing the nuts in the legitimate way—with a wrench—that was out of the question; a three-fold block and luff tackle would hardly have started them. In the case alluded to, the diameter of the centre was perhaps 14in., by about 20in. in length, and although for thirty minutes previous to the disaster everything was working properly, so rapidly did the bearing heat up that, if unattended to longer, it would probably have split the pillow block, there being no other possible outlet for the expansion. We have cited this case as one showing the importance of close surveillance of the detail in question, for not only is valuable time lost, but the machines themselves are greatly injured, sometimes involving costly repairs. In turning up shafts and bearings we have observed a reprehensible practice in some shops, and that is the use of the file. No good turner would employ such a tool to finish work that ought to be done by the cutter. The tendency of filing is to produce irregularity, and when the work is heavy and the speed slow, the use of the file is the height of absurdity, and ought not to be permitted by any foreman.

"The beautiful glaze produced by a sharp turning tool is as nearly akin to the working surface made on shafts by long running as any new journal can be, and consequently a well turned bearing is much less likely to heat and cause trouble than a filed one. When new shafts heat at the outset, a little time and patience will, in general, suffice to bring them down to their work; and in all cases it has been found the best practice in this country to bore the brasses from a sixteenth to an eighth of

an inch larger, according to the diameter of the shaft, so that the journals may bottom fairly, and not touch the sides at all. When shafts are 'side bound' they will invariably heat, because, in addition to the peculiar rolling friction of the work, there is added the weight of the metal, which, in shafts of fifteen and twenty tons, is an important item. Of course weight is present in any case, but in a well-fitted bearing it is dead, and not *wedging weight*, so to speak, such as exists in brasses which fit tightly to the sides of shafts. In our best machine shops files are virtually discarded in fitting large brasses to bearings; as, in addition to their awkwardness, there is the expense of them to be considered; besides this the peculiar harsh surface they leave is not favourable to a cool bearing. The scraper is substituted with good results, both of time and execution, as when well done the scraped brass is perfectly mirror-like, and is reduced to a working surface in a short time. Shafts may be well turned and properly fitted to their places, and yet heat beyond all control. This evil can sometimes be remedied by applying 'medicine' to the shaft with the oil, in the shape of blacklead, sulphur, and, in cases of great emergency, common quicksilver; this last substance is most excellent for curing journals that have been cut of the peculiar rough surface they acquire, as it produces a kind of greasy gloss that for a short time covers up the neglect or misfortune of the engineer. Where all other measures fail, the brass itself must be taken out and its composition changed—either it is too hard or too soft for the journal. We have known of a chronic hot bearing being cured in this way, after a great deal of time and labour had been expended in keeping it in running order, even to the extent of playing upon it with an inch hose throughout the trip. In the navy all the journal boxes on the new gunboats are hollow, and fitted with pipes through which a stream of water passes continually. Some merchant ships are also thus fitted.

"It is a curious fact in connection with bearings that they will occasionally defy all the efforts of experience and science to reduce them to obedience after they once heat thoroughly. It is possible that this effect may be traced to a want of proportion between the size and the labour on the shaft; but of two bearings both precisely similar (in fact on the same shaft), we have

found that the one which had the most duty to perform behaved the best. This is, of course, an unusual case, and is merely cited as an example of the previous remarks. When shafts set in brass boxes heat, they merely cut the shaft or the box; but when Babbitt metal is used, heating causes mischief that can only be repaired by overhauling. One peculiar effect of white metal is to reduce iron journals much more rapidly than brass; where brass boxes are lined with Babbitt metal, as is often the case, the iron journal will be found very much worn down where the white metal comes in contact with it, while the brass shell of the box is but slightly thinner than it was originally. This is owing to the peculiar toughness of the white metal. Where journals are run in this substance, and well lubricated, they acquire a perfect surface in a short time that very much lessens the friction of an engine or other machine. We have seen large engines 'turned over the centre,' when the steam gauge did not show a pound of steam. This is not wholly owing, as many suppose, to extreme delicacy of workmanship and tightness of the working parts, but to the vacuum produced in the cylinder by the almost infinitesimal portion of vapour admitted to it; and although the steam gauge may not indicate any tension whatever, there is a certain amount in the boiler which is transmitted to the cylinder, or else the machinery could not be moved. This is a little digression from the subject of bearings, but is in a measure connected with it; for while we stated, a few lines back, that free movement was not entirely dependent on easy bearings, we must admit that a stiffly connected engine will not turn the centres readily; where the resistance amounts to more than the vacuum is able to overcome, of course the engine must stand still.

"A great many engineers seem to think that slacking off a hot bearing will cool it, independently of other considerations. This is not always the case. Too much friction is, of course, a source of derangement, but excessive freedom is also a fruitful cause of hot bearings. This may be accounted for by the theory that the oil is pounded out by the journal in jumping up and down, and it thus comes in contact with the naked metal; the fact remains true, whatever be the reason assigned. Good lubricants, care, and cleanliness, will generally result in handsome bearings; no one will question that a large amount of power is

absorbed by a rough bearing, or one half oiled. Stop up the oil holes, and if the collars have much play back forth, arrange leather shields to cover the space; keep dirt out and oil in, and much better results will be obtained than where carelessness is practised and filth allowed to accumulate."

In addition to this we may only state our own experience, that if a brass is properly fitted, first with the file and then with the scraper, until the shaft bottoms properly, that is, having a bearing surface at the bottom of about one-third the total circumference, and being cleared away at the sides perfectly free, no fear need be entertained of such a journal heating as long as it receives the proper attention in oiling, keeping clean, &c. In locomotive practice this is particularly well attended to in fitting all axle box, connecting and coupling rod, and other brasses, and the result is that they are rarely known to heat; and it is well known that for both speed and hard work the locomotive has not its equal in any class of machinery.

A new antifrictional bearing material has been patented by Mr. N. J. Aimes of Manchester, which is said to bear extraordinary pressures, and with a minimum wear; its composition is described as follows:—"Animal fibre, plumbago, steatite, caoutchouc, or gutta percha, and any resinous gum or animal glue or size, are combined in proportions almost immaterial if the animal fibre be in sufficient excess; the composition being moulded or cut into the regular form.

"Vegetable fibres have been similarly used before; but inasmuch as animal fibres, such as silk, wool, hair, or disintegrated skin or pelt, are much more durable, and possess other superior qualities, the patentee employs it in combination with the aforesaid materials in contradistinction to vegetable fibres, as not having been hitherto so employed. In bearings, journals, or other frictional surfaces where water may be employed to assist in lubrication, he prefers to employ a resin or gum called 'rhinus copallinus' (gum copal), or a varnish made therefrom, as the medium to unite or bind together the other components, as such gum will best resist water in a heated state. The bearings, bushes, journals, steps, and other frictional surfaces are to be cast or otherwise produced with cavities, spaces, or excavations *for the reception* of the composition or filling, which is placed

next to and in immediate contact with the shaft or wearing surface; or, if required, the composition may, in some instances, be used solid, without the support or combination of metal or wood. The composition will be found suitable for such purposes composed of silk, wool, hair, or other animal fibre (either in a fibrous state or reduced to a pulp), two parts; plumbago, steatite, or similar lubricating or antifrictional material, half a part; and resinous substance, gum, or varnish, half a part; or in such other proportions as circumstances may require."

In concluding the subject of the steam engine we shall notice the most modern features in the construction of such engines, as also that of their details. The great bulk of steam engine work is now performed by the aid of machinery, very little fitting requiring to be done by hand in first-class establishments. Cylinder faces, valves, and links, as also innumerable details, are finished by the planing machine, self-acting lathe, and slotting machine. A very beautiful specimen of machine work was exhibited in the International Exhibition in the shape of a slot link for a marine engine, turned out by Maudsley, the slot, to the greatest nicety, splitting the centre punch marks determining the radius. Such a finished link, we should say without hesitation, was quite fit for regular working; indeed, we think that from such machine work the different parts would much sooner come to a good and true bearing than where the file was used, for, in the first place, only a few skilled workmen know how to hold their file so as to produce true work, and, in the second place, the very best filed work is far inferior to machine work. A good and exceedingly handy machine is the traversing drilling machine, which makes a most superb job of cotter holes and any other work requiring oblong slots. These are at all times expensive to cut by hand, and when done the workman has great difficulty in finishing such perfectly parallel. The specimens turned out by the machines exhibited at the International Exhibition presented a surface perfectly parallel, and shining like a mirror. The following practical article on the details of Steam-Engine Construction appeared in the '*Engineer*':—

"Nothing can be said against the working of a well-constructed beam engine, although it is both heavy and costly at the outset. One good *pattern of this class of engine, non-condensing, and*

with a single 22 inch cylinder, and 4 ft. 6 in. stroke, has 5 tons 2 cwt. in the columns, 3 tons 5 cwt. in the entablature, and 2 tons 5 cwt. in the beam, or 10 tons 12 cwt. in the parts mentioned, whereas all the other parts, exclusive of fly wheel (but including a sole plate of 7 tons 14 cwt.), weigh but 20 tons 7 cwt., the whole weight of the engine being 30 tons 19 cwt., exclusive of a fly wheel of 13 tons 10 cwt. The weight due to the beam, or say, in all, 11 tons, would be saved if the horizontal arrangement were adopted, and the latter would require a far less number of parts and wearing surfaces. It is difficult to discover exactly the grounds of objection so often made to the horizontal engine, although one commonly hears it said that the weight of the piston wears the bottom of the cylinder. The bottom of the cylinder may be slightly worn by the weight of the piston, but the principal wear of horizontal cylinders, whether in marine, locomotive or fixed engines, is invariably upon the upper side. Not only will an examination of a worn horizontal cylinder always disclose this fact, but the reasons for it are sufficiently apparent on a little reflection. All lubricating material admitted to the cylinder gravitates to the bottom, leaving the upper surfaces comparatively dry, and furthermore, whenever the piston is so loose as to 'blow steam,' this leakage will take place chiefly around the upper half of the circumference of the piston. Steam, in 'blowing' past a leaky piston, will rapidly wear both the cylinder and the packing. As for lubrication, we should never admit a drop of any lubricating material to a steam cylinder having gun metal packing rings, excepting only when the cylinder was steam jacketed with high-pressure steam, or when superheated steam was used. The packing of a well fitting piston ought never to be pressed outward with a force greater than 3 lb. or 4 lb. per square inch, and for this, and even a greater stiffness in the packing, the slight condensation of steam always going on within a cylinder, however protected, is sufficient for every purpose of lubrication. We know of large cylinders, both in marine and in land engines, which have been in use for years without other lubrication than that afforded by the steam, and they have maintained an excellent internal surface. We dwell upon this fact in connection with horizontal engines for this reason: if the cylinder be once regularly lubri-

cated, say with tallow, it will be found that lubricating material will be thereafter required, and that cutting is likely to follow if the tallow be discontinued. The cylinder should be run without tallow from the first. In horizontal engines, therefore, in which tallow is regularly used, the upper internal surface of the cylinder fails to retain its share, and cuts in consequence, although, as a rule, if no tallow were used at all, there would be no cutting. We are not stating a theory, but an indisputable deduction from the ascertained fact that marine and fixed steam engine cylinders seldom require other lubrication than is afforded by the steam.

"Locomotive cylinders, of course, must have lubrication, as the engines are often run for considerable distances (as down inclines and near termini), without steam. So, too, if the valve gear of a locomotive be reversed, as is sometimes done while the engine is still running forward, and without admitting steam, hot air and soot is pumped from the smoke-box, through the exhaust ports into the cylinders. But horizontal cylinders, even under the severity of locomotive service, do not require to be rebored as often as might be expected. And when reboring is necessary a horizontal cylinder may be bored *in situ* by means of a portable and easily applied apparatus, now very commonly employed on railways. The vertical cylinders of beam engines cannot be as conveniently bored in this way.

"At high speeds the momentum of a heavy beam would be very great. Think of a beam weighing several tons with its opposite ends working up and down at the rate of from 500ft. to 700ft. per minute! A great and useless strain would be thus brought upon the crank pin and upon the main journals at the end of every stroke. The Cornish engineers regard the great beams of their engines as counter weights, and however massive they may be, their momentum assists in forcing out the contents of the pump when, after the steam in the cylinder has begun to expand, its pressure has fallen below the mean load on the pump. Indeed, when it was first proposed to employ wrought iron engine beams, and thus, while gaining in strength, to save in weight, some of the Cornish engineers objected, because weight in the beam was the very thing they wanted, although one ton of iron upon the pump pole has more effect than two or three tons in the beam. In the Cornish engine, weight, in vibrating or reciprocating,

cating motion, is exactly what is required, but in a rotative engine it is the very thing to be avoided. The arrangement of the beam engine is better adapted to the employment of the parallel motion, but, as made with radius bars, no parallel motion can guide the piston rod in a truly straight line. There must be some, although not much, deviation on every stroke. But the slide bars and guide blocks of the horizontal engine, while ensuring absolute straightness of motion, need not cause much more friction than the best parallel motion. The plan of the horizontal engine is favourable for the employment of a long connecting rod, say of at least three times the length of the stroke. In this case the maximum vertical pressure on the guide bars will be one-sixth of the pressure on the piston, and as the mean vertical pressure throughout the stroke will (supposing the engine not to work expansively) be nearly 70 per cent. of this, the mean vertical pressure for the whole stroke will be about $11\frac{1}{2}$ per cent. of that on the piston. As the co-efficient for a well lubricated cross-head ought not to exceed one-eleventh of the pressure, we have as the loss by the friction of the guides about one horse-power of every hundred. This is not much, certainly. Speaking of guides, we should give a much more liberal allowance of bearing surface than is provided by most engine makers. The guides wear all the better if the maximum vertical pressure upon them does not exceed 25 lb. per square inch, and for a 16in. cylinder, working 50 lb. steam and having a good long connecting rod, we should not make the cross-head bearings less than 90 square inches in extent, or say two blocks, one on each side of the piston rod, and each 3in. wide on the bearing and 15in. long. We would always make cast iron cross-heads, with the pin either cast in, or fitted in, in wrought iron. As long as one end of the piston rod is keyed within a cast iron piston, the boss of which is seldom over-strong, it appears needless to forge a costly 'shape' to receive the other end.

"All land engines should, and, we believe, sometime will, be regulated by the action of the governor upon a variable expansion gear, so as to dispense with throttle valves and wire drawing the steam. Mr. Petrie of Rochdale, Mr. Brownlee of Glasgow, and others, have applied arrangements for this purpose. The *French makers*, as MM. Farcot, and others, have adopted this

system, but it is perhaps best carried out in a class of engines of which two, of Prussian make, were exhibited in the late Exhibition, and which were exact copies of the engine known in the United States as Corliss' engine. One made by the Corliss Steam Engine Company, of Providence, Rhode Island, United States, is now working at Messrs. A. Pirie and Co.'s paper mill at Aberdeen. These engines are regulated twice during each revolution, taking, according to the requirements of the work, from one-twentieth of a cylinder-full to an entire cylinder-full of steam at each stroke. Engines of the same construction, employed in rolling mills, work under a load varying from 60 to 360-horse power within 5 seconds, and yet without any sensible alteration in their speed. Mr. Corliss employs valves and valve gear of peculiar construction, and connected in a peculiar manner with the regulator. We have no doubt that Pitcher's hydraulic governor, as made by Messrs. Farmer, of Salford, might be usefully applied to shift a link motion, and thus to accomplish in part the purpose of Corliss' valve gear.

"We believe it to be time, with increasing pressures and speed, to make longer bearings on engine shafts. The Boulton and Watt pumping engines at Stoke Newington furnish a notable instance of misproportion in this respect. With 5ft. cylinders and 8ft. stroke, and with a 25ft. fly wheel weighing 60 tons (the rim alone, 24in. by 17in. nearly, weighing upwards of 50 tons), the journals are but about 15in. in diameter and 20in. long. These engines, as is well known, have been almost reconstructed at the pump end, but although new plummer blocks have been put in, with $4\frac{1}{2}$ in. holding down bolts going 36ft. deep into the foundations, the fault of too small journals has not been corrected. We lately saw a pair of 18in. cylinder engines working 50 lb. steam, and having $6\frac{1}{2}$ in. journals apparently but 8in. long. On the other hand, we may observe that one of the best working pairs of horizontal engines we have ever seen, and having 12in. cylinders, $3\frac{1}{2}$ ft. stroke and working 60 lb. steam, had $6\frac{1}{2}$ in. journals $15\frac{1}{4}$ in. long, the shaft being of cast iron.

"Piston valves may yet be found to answer best for steam engines. Messrs. Simpson and Co. have already used them very successfully for large pumping engines, the 14-in. pistons forming the valve having a single gun metal ring 6in. wide on the face,

and feebly pressed out by a small spring. There is a difficulty with self-adjusting packing on piston valves. The rings are likely to spring out on passing the exhaust ports, just as Ramsbottom's wire packing springs out at the ends of the cylinder where counterbored, and in passing the induction ports the rings of piston valves will, if fitting elastically, be pressed in by the steam. There is an adjustable, but not self-adjusting, packing for piston valves, of which we have heard good accounts. Each piston of the valve has a broad cast iron ring, projecting over the edge of the junk ring as well as over the edge of the plate cast on the central boss. The central boss is turned so large that the ring requires to be sprung on, and its tendency when on is not to expand, but to contract closely around the turned boss, which serves as the body of the piston. The ring is cut open at one point, and to counteract its contraction a wedge-shaped key is forced by a screw between the ends where the ring is cut open. By means of this key, which fills out the full circumference of the piston, making it perfectly steam tight, the ring can be set out to any degree of tightness, while at the same time no pressure of steam can press the ring inward on passing a port. Although these valves are not self-compensating they work steam-tight for a very long time before the key requires to be tightened to set out the packing ring. We have seen them working rapidly with the end covers of the piston valve chamber removed, and there was no perceptible leakage of steam. The least possible power is required to work well made piston valves, whereas, with short stroke engines especially, a great amount of power is absorbed in working large slide valves. It is questionable whether piston valves really require packing, or rather whether it is not cheaper to turn them out of the solid, and to replace them when, after a considerable time, they begin to leak much steam. We are now speaking only of small engines. Mr. David Joy, of Middlesboro', has employed unpacked or solid cylindrical steam moved valves for a considerable time. He has made them up to $5\frac{1}{2}$ in. in diameter, and worked them at 200 strokes per minute, under 50 lb. pressure. When made with long bearing surfaces, the valve and bored chamber in which it works being of the same metal, say cast iron, they wear a very long time without leaking *any notable amount of steam.*"

The writer now proceeds to the consideration of pistons; before, however, concluding his article, we would here interpolate a very excellent and practical paper read before the Institution of Mechanical Engineers, by Mr. George M. Miller, of Dublin, on the subject of metallic packing for steam engines and pumps.

"This packing consists of two rings, pressed outwards against the cylinder by the pressure of the steam as it acts on the alternate faces of the piston, without the use of any springs. This construction of piston is used by the writer in the locomotive engines on the Great Southern and Western Railway of Ireland. The piston is of cast iron, 2 in. in thickness and 15 in. diameter. Two square grooves are turned in the edge of the piston, $\frac{3}{8}$ in. in width and $\frac{3}{8}$ in. apart, and a corresponding steel ring is fitted into each groove, the rings being divided at one part with a plain butt joint, and sprung over the piston into their places. Two small holes, $\frac{1}{8}$ in. in diameter, open from each face of the piston to the bottom of the nearest groove, whereby the steam is admitted behind the packing ring and presses it out against the cylinder so long as the steam is acting upon that face of the piston. The alternate action of the two rings is continued as long as the steam is acting on the piston, one of them being always pressed steam-tight against the cylinder.

"Another form of the piston has been used in cases where the piston is desired to be flush on both faces or to fit a cylinder with flat covers; in this a circular flat head forged upon the piston-rod is fitted between the turned faces of the two halves of a cast-iron piston, which are held together by turned pins riveted over, forming a hollow piston flush on both faces, fast upon the piston-rod, and without any loose part besides the two packing rings.

"The ends of the rings, where divided, are made either with a butt joint or a lapped joint. The piston body is turned to pass through the cylinder easily; and the joints of the rings have been found to be practically steam-tight. In some cases the joints have been tongued, as shown, but in the writer's experience this has not been found requisite; the butt joint has invariably worked well, whilst it has the advantage of perfect simplicity of construction. In pistons where the packing ring travels over the opening of the cylinder port, a small stop is fixed

in the bottom of the groove, entering a short slot in the packing ring, to prevent the ends of the ring coming opposite the cylinder port, but still leaving the ring free to travel round a little in the piston grooves; but it is preferred for the packing rings not to travel over the cylinder ports.

"These steam-packed pistons have been used more than seven years in the locomotives of the Great Southern and Western Railway, and have proved so satisfactory and advantageous that their use has been extended to all the 94 locomotives working upon that line. The following are the results of the working in the engines running from Dublin, as regards the durability of one set of rings, the period of their wear, and the mileage of the engines whilst wearing them out. Nineteen engines working with one set of steel rings averaged 33,020 miles and $16\frac{1}{2}$ months' running, one engine having worked for 3 years and run as much as 98,073 miles with one set of packing rings. Five engines working with one set of brass rings under the same circumstances averaged 30,986 miles and 19 months' running, the greatest work amongst them being $2\frac{1}{4}$ years and 43,197 miles. Twenty other engines with steel rings, which are still in use, have also averaged 40,444 miles and 21 months' work, one of these having worked for $3\frac{1}{4}$ years and run 94,399 miles with the original set of rings.

"The general result of the above is that one set of steel packing rings have lasted 37,000 miles and 19 months' work, and one set of brass rings 31,000 miles and 19 months' work, the difference in durability being about 16 per cent. in favour of the steel rings. In some of the individual cases of the pistons with steel rings, a very considerable variation from the average result of 37,000 miles is found in the durability of the packing rings, some of them having lasted $2\frac{3}{4}$ times the average, and some only as much below the average. In the cases of the brass rings the variation is not so great, amounting to $1\frac{3}{4}$ times the average in the highest, and about as much below the average in the lowest. This variation in wear has not been fully accounted for: it may have occurred from a different character of metal in the cylinders, from priming of the boiler, and from the presence of grit in the water; but the writer has reason to believe that *the rings have been frequently put in to work and set with a*

pressure upon the cylinder from their own elasticity, thus causing a source of wear. It is found the best plan to turn the rings to the exact diameter of the cylinder, and to put them in without any spring upon them, so that they are not subjected to any wear except when the steam is acting on them. The steel rings are now slightly tempered, to admit of their being sprung into the grooves without altering their form. In all these pistons the steel packing rings were $\frac{3}{8}$ in. thick originally, and $\frac{3}{8}$ in. wide, and they were worn down to about $\frac{1}{8}$ in. thick in the thinnest part before being removed. The brass rings are worn down from 7-16ths in. until they are $\frac{1}{8}$ in. thick. Specimens were exhibited of steel rings from four engines that have worked 38,000, 61,000, 84,000, and 96,000 miles respectively, since first put into the pistons. It must be remarked, that, when opportunities occur, as when engines are under repair, the rings are taken out and reset to the size of the cylinder.

"It is found in practice that two steam ports of $\frac{1}{8}$ in. diameter are quite sufficient for each of the steel packing rings. The rings must be made to fit easily in their grooves, so as to move freely, with a clearance of 1-16ths in. at the bottom of the grooves for the steam to pass round behind the rings. No difficulty has been experienced from the steam passages becoming stopped up by a moderate use of tallow in the cylinders.

"The use of this piston-packing in locomotive engines has been productive of economy by reducing the friction, and by prolonging the wear of both pistons and cylinders. It will be observed that only one ring is in action at the same time, and that when the steam is shut off, as in descending inclines and approaching stations, the piston is free to move without any friction. The cylinders of the four engines from which the specimen rings exhibited have been taken, show a highly polished surface, are very little worn, and are nearly parallel throughout. The operation of putting in these rings so as simply to fit the cylinder is extremely easy, whilst great care and skill are required in giving springs the requisite degree of elasticity, and in making them with maintain it.

"A set of brass packing rings was also exhibited, taken out of the pistons of a pair of vertical stationary engine cylinders at the Dublin Railway station, in which they have been in constant

work for the last four years, with a pressure of 50 lb. steam. The diameter of the cylinders is $19\frac{1}{2}$ in., and the rings were originally $\frac{5}{8}$ in. thick and $\frac{3}{4}$ in. wide; they are now worn down to 5-16th in. thick.

"A number of stationary engine pistons are working with these packing rings, and they have proved very durable and thoroughly satisfactory, giving an advantage in reduction of friction, and in preserving the cylinder face in perfect condition. In one case of the engine of the Oldbawn Paper Mill, near Dublin, with vertical cylinder 18 in. diameter and $2\frac{1}{2}$ ft. stroke, working with 50 lb. steam, the cylinder had previously been worn considerably out of truth and much grooved, and one of these pistons was put in having two steel rings of $\frac{3}{4}$ in. width and $\frac{3}{8}$ in. thickness, and was in constant work for four years without the packing rings requiring renewal. They have lately been taken out for examination, and were found to be still $\frac{1}{4}$ in. thick; and the cylinder, from its previous defective condition, has been brought completely to truth throughout, with a highly polished surface.

"These packing rings have also been used for four years for pump buckets, and have proved very satisfactory. In one case of a double-acting pump 8 in. diameter, the two packing rings are of brass, $\frac{3}{8}$ in. wide and 5-16ths in. thick, and are pressed out by the pressure of the water acting at the alternate faces of the bucket through two ports, $\frac{1}{8}$ inch diameter, similar to those in the steam pistons. This pump had two years' constant work at quarries and bridge foundations upon the Great Southern and Western Railway, before the packing rings required renewal.

"In the case of single-acting pumps the bucket has only a single packing ring with ports opening from the upper side. A pump bucket 5 in. diameter has been working constantly for $2\frac{1}{2}$ years at a station on the railway near Dublin. This bucket was exhibited, having been taken out for the purpose; the packing ring was originally $\frac{1}{2}$ in. wide and $\frac{1}{4}$ in. thick, and has worn less the 1-16th inch in the $2\frac{1}{2}$ years that it has been working up to the present time. As the diameter in this case is too small to allow of the ring being sprung over the body of the bucket into its place, it is put in by means of a junk ring screwed on at the under side of the bucket.

"An application of the same construction of packing that has also been made to the gland packing of a 9 in. pump plunger, in which two brass packing rings are used, $\frac{1}{4}$ in. wide and $\frac{3}{8}$ in. thick, just like the piston packing rings, except that they act in the opposite direction, being pressed inwards upon the plunger by the pressure of the water through the ports.

"Mr. Miller exhibited specimens of the steel packing rings from the pistons of four locomotives which had run from 38,000 to 96,000 miles; and also the brass packing rings from the pistons of the stationary engine, together with the bucket of the 5 in. single-acting pump referred to in the paper.

"During the discussion which followed, Mr. J. Fernie said he was glad that the subject of packing rings for pistons, which were such an important part of a steam-engine, had been brought forward in the paper just read. He observed that steel packing rings had not been found to wear well in other instances in which they had been tried, and moreover they cut the cylinders; and he inquired whether the cylinders in which the steel rings had been working for so long a time were made of a very hard quality of metal.

"Mr. Miller replied that the cylinders were cast as hard as they could be made, consistently with allowing of the subsequent boring. The packing rings were made of common shear steel, and sometimes wore down irregularly in thickness, but in many cases the wear was regular.

"Mr. J. Fernie asked how the steel rings were made.

"Mr. Miller said the steel was rolled in lengths of the required shape, but slightly tapering in section from the outer to the inner face, so that when bent into a circle the two edges of the ring became nearly parallel, giving the same depth of ring throughout its whole thickness. The bar was then bent in a miniature plate-bending machine, hammered to the size of the cylinder, and fitted into the groove in the piston by simply filing, without any other work being spent upon it. At first the rings were turned in a lathe out of a steel cylinder and then cut across, but it was found better to get steel rolled of the proper section for the purpose, and afterwards bend it and fit it by filing.

"Mr. F. J. Bramwell inquired what amount of spring was given to the packing rings before they were put in their place,

and whether the piston had ever been tried without admitting the steam behind the rings, in order to see how far it would be rendered steam-tight by the pressure of the rings alone without the steam behind them.

"Mr. Miller explained that the packing rings were put in without any amount of spring of their own, being made no larger than the diameter of the cylinder, in order that there might be no pressure against the cylinder, and therefore no wear whilst running with the steam shut off.

"Mr. J. Fernie remarked that the steel packing rings in Mr. Ramsbottom's piston, generally three in number, were set with a certain amount of spring in themselves, by which the required pressure against the cylinder was obtained; and that plan required the cylinders to be of rather hard metal to stand the constant pressure in working. He inquired whether the brass packing rings that had been used had been adopted for the purpose of working in soft cylinders.

"Mr. Miller said the rings first used with this mode of packing were brass, and after some time a set of steel rings was tried, the experiment being proceeded with rather cautiously from fear that the steel rings might cut the cylinder; but it was found they did not do so, if fitted in without any spring whatever in the rings themselves, but with only the steam behind pressing them against the cylinder. The result was that it very rarely occurred now that a cylinder required rebor-ing: the cylinders not only preserved a fine smooth surface, but kept more parallel than under the old modes of packing the pistons. The reason of using the steel rings and discarding the brass was that the steel lasted about twice as long.

"Mr. J. Fernie asked what was the weight of the steam-packed piston for a locomotive cylinder of 15 in. diameter.

"Mr. Miller replied that the weight of a piston of that diameter was $64\frac{1}{2}$ lb. without the rod, which was $2\frac{3}{8}$ in. diameter; the piston was 2 in. thick.

"Mr. J. Fernie said they had tried some pistons on the Midland Railway on this principle of packing by the pressure of steam behind the rings; they were wrought iron pistons forged solid on the piston rods, and the packing rings were of brass $\frac{1}{2}$ inch square in section. A very long mileage was got out of these

rings, but it was found that with solid pistons there was a great deal of trouble from the necessity of getting the cross-heads off to draw the piston out, whenever it was wanted to do anything to the piston or look at the packing rings; and they had therefore now gone back to the old-fashioned piston with a junk ring bolted on the face for getting at the packing rings. The bearing surface was now reduced to 1 in. in the pistons; there were two $\frac{1}{2}$ in. packing rings, and these gave a longer mileage than used to be got out of two $1\frac{1}{4}$ in. rings. A great width of bearing surface was not required, but a small bearing surface was preferable, provided the rings were made to fit the cylinder accurately all round; and Mr. Ramsbottom certainly had the credit of having first called attention to the advantage of narrow packing rings well fitted. The 16 in. piston now used in the Midland locomotives weighed $1\frac{3}{4}$ cwt., including the piston rod, having been reduced in weight 28 lb. below the previous make, in consequence of which a longer mileage was got out of the packing rings; the wear of the cylinders was also greatly reduced, a highly polished surface being maintained. Formerly there used to be a great deal of trouble from the cylinders wanting reboring, but now with the narrow packing rings and light pistons this was quite removed. He thought highly of the steam-packed piston, and the results obtained in the durability of the packing rings were certainly very extraordinary, 90,000 miles far exceeding any mileage previously attained. In his own experience about 20,000 miles was the durability of a set of $\frac{1}{2}$ in. square brass rings, and then they would want setting up twice or three times during that period. He enquired how often the steel packing rings had been set up before they were worn out.

"Mr. Miller said the packing rings had not been examined and set up at stated times, but whenever the engine happened to be in for casual repairs the piston was taken out, and the rings examined and set out if required, by slightly hammering them all round to bring them again up to the exact diameter of the cylinder; or they were replaced by new rings if worn out. The results of mileage with the different sets of rings were drawn from a return of the exact mileage of all the engines that were working under his own observation.

"Mr. F. J. Bramwell thought there would always be nearly

the full pressure of the steam behind the rings that there was in the cylinder, judging from the quickness with which the steam filled the cylinder of an indicator through a small orifice.

"Mr. Miller said that with the brass packing rings first tried the holes behind the rings were drilled $\frac{1}{4}$ in. diameter, but that size was found too large, and they were therefore reduced to $\frac{1}{8}$ in. in diameter, which proved to be sufficient for obtaining the required pressure to make the piston steam-tight in the cylinder.

"Mr. C. F. Beyer, the Chairman, inquired whether the piston body was turned much smaller than the cylinder or only an easy fit.

"Mr. Miller replied that the piston body was turned down to about 1.32 in. smaller diameter than the cylinder, so as to pass easily through it.

"Mr. F. J. Bramwell asked whether the packing rings filled out to the size of the cylinder as they become worn, or whether when the steam was off they returned to their original inside diameter.

"Mr. Miller replied that when taken out after a great deal of wear the packing rings were slightly smaller in diameter than the cylinder, and then required setting out by hammering. Sometimes they were perfectly equally all round, and sometimes more at the ends or in the middle.

"After some further discussion, the Chairman remarked that, after making and employing a great many descriptions of pistons, he thought the steam-packed piston described in the paper was a very good one, and it had the great advantage of being very simple in construction. Formerly, it was a great object to keep the steam out of the piston, on account of the internal packing springs; but in this piston the steam was admitted inside to act as the spring upon the packing. The practical feature of the new pistons was their great simplicity of construction; but to Mr. Ramsbottom was certainly due the credit of first simplifying the construction of pistons to so great an extent. He considered the piston now described ought undoubtedly to work well, because there was so little about it to get out of order, and it could not do otherwise than prove highly satisfactory. He proposed a vote of thanks to Mr. Miller for his paper, which was passed."

In confirmation of the foregoing excellent paper, we may say

that our experience of Mr. Ramsbottom's packing of hard drawn low moor rings, simply sprung in to the cylinder, is, that it is the most simple and most economical packing in existence,—experience which is fully borne out by the London and North-Western Railway Company, and other lines using it; we should say, however, that the admission of steam behind the rings is a decided improvement, and likely to equalize the spring at the proper time, and thus make the rings run till they were completely worn through, Ramsbottom's packing having frequently to be taken out and replaced with new rings before the old ones are quite worn out, owing to their having lost their spring. Continuing again in conclusion the '*Engineer's*' article:—

"Mr. Richard Roberts made solid locomotive pistons, 11 in. in diameter, in 1834, and they answered well for a considerable time on the Liverpool and Manchester and Dublin and Kingstown Railways. A late attempt, however, to employ solid locomotive pistons on the North London Railway completely failed. Mr. Humphrys, of Deptford, has for many years made donkey engines with solid cast iron pistons, and one of these which we have lately seen, although but 2 in. wide for a diameter of $10\frac{1}{2}$ in., and although it had done a great deal of work, was in excellent condition, and not perceptibly smaller than the internal diameter of the cylinder. We should not, however, like to depend upon them unless their breadth, as measured on the wearing face, was equal to at least one-half of their diameter.

"If engineers chose to use them they would find cast iron eccentric hoops better than those of any other material. They wear as well as gun metal where, as in the case of well proportioned eccentrics, the pressure per unit of area is not great, and cast iron is free from the 'spring' which gun metal hoops have when not made exceedingly heavy.

"If, however, gun metal wearing surfaces be preferred, there is no cheaper or better way of making them than that adopted, if not invented, by Mr. Humphrys, of Deptford. He employs a strip of hard rolled brass, say of No. 13 gauge, and cut about 1 in. shorter than the circumference of the eccentric as well as a trifle narrower than its width. This strip is drilled with several holes, to allow of the free passage of oil, and then bent around the eccentric, the hoop being bored out large enough to go on over

it. The brass is free to turn either with the eccentric or to rest within the hoop, as may happen, and as it sometimes turns and is sometimes at rest, it really affords a double wearing surface. It is more durable by far than any other kind of eccentric hoop.

"The time will doubtless come when, for most purposes, single cylinder engines will be preferred to double cylinders. Double cylinders have one especial advantage; if one engine break down another may generally be worked. On the other hand, double cylinder engines, having twice the number of parts, are always more likely to break down than single cylinders. Indeed, for some purposes, double cylinders, or coupled engines, are, if not almost impracticable, at least troublesome. Coupled blowing engines are so owing to the great and rapid alternations in the strain on the coupling shaft. The intermediate shafts of steamships are always the most troublesome in respect of breakages, and for large double cylinder oscillating engines the Americans have found it best on this account to place the two cylinders one in front of and the other behind the shaft, the crank pins for both being in nearly the same vertical plane and connected by a 'drag link.' As for getting a single cylinder engine 'off the centres,' none but a careless engineman would (except in the case of a locomotive) allow it to stop on the dead centres. Nearly all the large American river boats, coasting steamers, and ferry boats, have single cylinder engines, and several with 105-in. cylinder and 12ft. stroke are now being made for ocean steamers on the Pacific. An engineer who would stop one of these engines on the centre would, after one or two reprimands, be dismissed. Even for large screw engines, with from 70-in. to 84-in. cylinder, and from 3ft. to 3ft. 9in. stroke, the Americans more commonly employ single cylinders, and with much advantage.

"The strong point with the advocates of coupled engines has, however, been uniformity of motion. With a heavy fly-wheel, however, and especially at the higher speeds now in favour, single engines run with a great degree of uniformity, enough we believe for any purpose, even if it be cotton spinning on fine counts. We will suppose a 16-in. cylinder and 4ft. stroke, working with 50 lb. steam at 60 revolutions per minute. Let the fly-wheel be 14ft. in diameter at the centre of the section of the rim, and let the weight of the rim be 20,000 lb. Mov-

ing, as it then will, at 44ft. per second, the fly-wheel rim contains a reserve of 596,232 foot-pounds of mechanical power, and in falling off from 60 to even 59 revolutions, 17,129 foot-pounds of this power must be liberated, this alone being equal to a mean pressure of 21 lb. per square inch on the 16-in. piston throughout its stroke of 4ft. When we consider that the moving parts of the machinery driven have, in the aggregate, a large amount of momentum, or stored up mechanical power, we may safely trust the heavy and rapidly moving fly-wheel to redress, almost completely, the irregularities resulting from the variable pressure transmitted to the crank. In the case of a flour mill with several pairs of heavy 4ft. stones, the upper stone making from 130 to 150 revolutions per minute, a considerable and prolonged variation in the power must occur in order to sensibly alter the speed.

"We are gratified by knowing that some of the most eminent engineers, both in this country and abroad, agree with us in our preference for a single cylinder. We will not mention the names of English engineers who share our views, but we may say that when we lately had occasion to discuss this point with Mr. Horatio Allen, the foremost American mechanical engineer, he assured us that if he had to construct a marine engine of great power he should unhesitatingly adopt a 150 in. cylinder in preference to two of 106 in. each. The success already attained abroad with single 105 in. cylinders affords good ground for this partiality."

DIVISION FOURTH.

STEAM FIRE ENGINES.

The steam fire engine subject is, comparatively speaking, one of yesterday. It is true, that many years ago such engines had been proposed both here and in America, but it is only recently that they have been recognised as available for the extinction of fires. In July of the past year a series of extensive trials took place at the Crystal Palace, Sydenham, during which

many important facts were elicited. The trials were competitive, and a fund was subscribed by a number of noblemen and gentlemen from which £700 was offered in the shape of prizes for the best engines. A committee was formed for the purpose of deciding upon the merits of the various engines, of whom the Duke of Sutherland and the Earl of Caithness were working members, Captain Eyre M. Shaw, Superintendent of the London Fire Engine Establishment, being honorary secretary.

Before stating the results of such a trial we give the following description of the various engines competing, which we have compiled from the official report of the Committee and the '*Engineer*':—

"The engines entered for trial were two by Messrs. Shand, Mason, and Co., of Upper Ground-street, Blackfriars Bridge; two by Messrs. Merryweather and Sons, of Long-acre; one by Messrs. Easton, Amos, and Sons, Southwark; one by Mr. William Roberts, of Millwall; and three American steam fire engines, all, we believe, virtually entered by Messrs. Wellington Lee and Co. of Cannon-row, Westminster, although one appeared in the name of Butt and Co., and another in that of 'Steam Fire Engine Company, Manhattan, No. 8,' New York. Messrs. I. W. Gray and Son of Limehouse, also brought an engine upon the ground yesterday morning, and the engine exhibited by Messrs. Merryweather and Sons last year in the International Exhibition was also present, but weighing rather more than three tons, was excluded from competition.

Messrs. Shand, Mason, and Co.'s large engine weighed 57 cwt. 1 qr., without coal, water, hose, or other gear, the extra weight of which is not considered by the committee in their limitation to weights of 3 tons and 1½ ton, respectively. The boiler is upright, 2 ft. 8 in. in external diameter, with, we believe, 296 fire-tubes, of brass, 1 in. diameter, and presenting, together with the submerged smoke-box, 108 square feet of heating surface. The fire-box is gradually enlarged below its junction with the barrel, being 3 feet 9 in. in outside diameter at the bottom, and presenting 19¾ square feet of heating surface. The whole height of the boiler (barrel and fire-box) is 5 ft.; the steam space 7 cubic feet, the water space 4·52 cubic feet (28¼ imperial gallons). The tubes are pitched very closely, the clear

space between them being, we believe, but $\frac{1}{4}$ in., but instead of occupying the whole circle of the tube plates, they are arranged in four symmetrical groups, with a considerable clear waterway between these groups. The smoke-box is surrounded with a water space, and the water rises above it so as to surround the chimney. In order to diminish the quantity and weight of water carried, it is not permitted to come in contact with the inner surface of that part of the barrel of the boiler immediately surrounding the tubes, but is kept 2 in. or 3 in. away, all round, by a thin partition placed annularly within the boiler, and tightly joined below to the barrel itself, while the top of the enclosure thus formed is open to the steam, which thus finds its way down a considerable distance below the water level. The barrel of the boiler is fastened to the fire-box by rings of angle iron faced and secured by bolts and nuts. The smoke-box heads are put in in the same way, and thus the boiler may be taken to pieces in a short time, and without the least injury to any part. The water space around the fire-box is very narrow, less, we believe, than $\frac{3}{4}$ in., but, as a whole, the boiler carries its water very well indeed. The framing of the engine is formed of two deep slabs of wrought-iron, supported on easy springs, the wheels being large for fast travelling. The fore wheels are combined in a wrought-iron fore-locking frame. There are two horizontal steam cylinders, placed side by side, the bore being $8\frac{1}{2}$ in., the pistons of 9 in. stroke, working each a double-acting gun-metal pump of 7 in. bore, the area of the steam pistons to that of the water pistons being as 1.475 to 1, the stroke of both steam and water pistons being the same. The water passages are of gun-metal, the pump valves being of india-rubber discs, having an area of 12.141 sq. in. and $\frac{3}{4}$ in. lift. The suction pipe was 4 in. diameter, hose $2\frac{3}{4}$ in. diameter. Slotted cross-heads are employed to give a rotary motion to control the length of stroke, steady the action of the engine (fly-wheels being applied), and for working the valves. The ordinary speed of the engine is about 120 revolutions per minute, the cranks of the fly-wheel shaft being set at right angles, and a large air vessel being used to give a steady jet. The ordinary working steam-pressure is 130 lb. per square inch, although this was not kept up on trial. The boiler may be fed by either of two feed pumps

or by a Giffard's injector. The steam from the cylinders is turned into the chimney, the orifice of the blast pipe being made so as to be easily varied in size. A single jet or 'blower' of steam may be also turned directly from the boiler into and up the chimney. This is of great advantage in starting, as, after steam of, say 15 lb., has been once raised, a strong draught may then be obtained, thus raising the pressure quickly to 100 lb. or 150 lb.

Messrs. Shand, Mason, and Co.'s small engine weighs $29\frac{1}{2}$ cwt. Its boiler is of the same construction as that of the engine just described, the diameter of the barrel being 25 in., and that of the fire-box, measured at the bottom, 34 in. The height of the boiler is 4 ft. 6 in. The small brass tubes, 12 in. long, present 48 square feet, the heating surface in the fire-box being $14\frac{1}{2}$ square feet. The water space in the boiler is $16\frac{1}{2}$ gallons, or 2.64 cubic feet, the steam space 3.62 cubic feet. The working pressure is 160 lb., although 180 lb. has been reached, the boiler having been proved to upwards of 300 lb. A single feed-pump and an injector are provided. There is a single vertical steam cylinder, 7 in. in diameter, the piston having a stroke of 8 in., and being directly connected by two piston rods to the plunger, $6\frac{5}{8}$ in. in diameter, of a bucket and plunger pump, 9 in. in diameter. The area of the steam piston to the displacement by the plunger is as 1.12 only to 1, while the area of the piston as compared with the difference between the bucket and plunger is as 1.32 to 1. This apparent difference is compensated by the section of the piston rods. The pump, and the parts connected with it, are of gun-metal. The plunger is hollow, and a connecting rod, jointed at its lower extremity, turns a crank shaft which revolves between the two piston rods. The crank shaft carries a fly-wheel and an eccentric for working the valve. The suction valves are in the form of india-rubber discs $2\frac{3}{4}$ in. diameter, seven being employed, and having a total area of 21 square inches with $\frac{3}{8}$ in. lift. The delivery valves are similar, but only six are employed. The suction pipe is $4\frac{1}{2}$ in., hose $2\frac{3}{4}$ in. The air vessels are very large, comprising a roomy space around the pump barrel, and a tall cylinder besides. The framing of the engine consists of two parallel steel tubes, apparently about $4\frac{1}{2}$ in. in diameter, polished outside, and serving within as re-

ceptacles for the branch pipes and fire irons. The wheels are large, those in front being fore-locking, and easy springs are used, both the ordinary plate springs and spirals being fitted over the axle of the larger wheels. The ordinary number of revolutions of the engine is said to be 160 per minute.

Messrs. Merryweather's large engine weighs, we understand, 2 tons 18 cwt. 1 qr. 7 lb. The construction of the boiler is such that, after having been once filled, it cannot be entirely emptied, and thus with a quantity of water in the tubes estimated to weigh 3 qrs. 1 lb., the weight, as taken, was 2 tons 18 cwt. 0 qrs. 8 lb. This engine is named the Sutherland. "The boiler is of the vertical tubular description, having an outer shell of homogeneous metal $\frac{5}{16}$ in. thick double riveted. The tube and top plates are of Lowmoor iron $\frac{1}{16}$ in. thick. Diameter of shell 3 ft. 6 in., height 5 ft. The arrangement of the tubes in this boiler, which is similar to Perkins' one, is as follows:—The tubes are of solid drawn copper, and attached to the fire-box crown, so that they are filled with water while the fire circulates around them. To ensure a proper circulation, a centre tube, open at both ends, is introduced into the water tubes, having its top flued out like a funnel, so as to deflect the steam currents out of their course and permit a free course to the entrance of the water. By this means, a perfect circulation of water in the tubes is maintained, so much so, that the greatest available heating surface is much augmented by the superior circulation. The tubes are closed at the bottom end, being simply suspended from the fire-box crown, while the heated air, &c., escapes by a centre flue into the chimney. The total tube surface is 192·5 sq. ft., while that of the fire-box is 14·5 sq. ft. The framing of the engine is of angle iron. There are two horizontal steam cylinders placed side by side, each of $8\frac{5}{8}$ in. bore, the pistons having the usual stroke of 24 in., and working directly the pistons of two double-acting pumps, $6\frac{1}{2}$ in. in diameter, and of the same stroke, the ratio of the area of the steam to that of the water pistons being as 1·983 to 1, or very nearly 2 to 1. No crank shaft is used, the steam valve of each cylinder being worked from the piston rod of the other. An ingenious arrangement—too much so, we almost fear—is employed to prevent the pistons from striking the cylinder covers, and to ensure the proper going of the pistons, or, in other words to keep

them in the same relative positions to each other which they would occupy if connected to cranks at right angles to each other." The suction valves of the pumps are of gun metal, india rubber faced, 10 in. long, 1.375 wide, and having a lift of 1 in.; the total area being 13.75 sq. in. The delivery valves are similarly constructed, 10 in. long, 1.25 in. wide, the area being 12.5 sq. in., and the lift 1 in. bore. Size of suction pipe $5\frac{1}{2}$ in., hose $2\frac{1}{2}$ in.

Messrs. Merryweather's small engine, the Torrent, weighed 30 cwt. 1 qr. 12 lbs. The boiler is of a similar description to their larger engine, being composed of an outer shell of homogeneous metal full $\frac{1}{4}$ in. thick, 48 in. high, and 28 in. diameter. Top and tube plates were of Lowmoor $\frac{9}{16}$ in. thick. The tubes were of solid drawn homogeneous metal, having a total surface of 57 sq. ft.; the fire-box surface, including flue, being 75 sq. ft. The water space of this boiler, when at work, contains from 15 to 30 gallons. The steam space has a capacity of about 4 cubic ft. "There is but one steam cylinder, which is placed horizontally. the diameter being $6\frac{1}{2}$ in., the stroke 12 in., and the double acting pump, worked direct at the same stroke, $4\frac{3}{4}$ in. Ratio of steam and water areas, 1.87 to 1. This engine has no crank shaft. The piston rod works a very small slide valve, which admits steam upon a piston valve answering as the main valve." The pump valves were of gun metal, leather faced. Suction, 9 in. long, 1.0625 wide, having a lift of 1 in. Delivery 9.5 in. wide, 1 in. wide lift, 1 in. bore. The suction pipe was $3\frac{1}{2}$ in. diameter, the hose being $2\frac{1}{2}$ in. diameter.

Messrs. Easton, Amos, and Sons' engine, the Sabrina, weighs 2 tons $18\frac{1}{2}$ cwt., its original weight having been rather more than 3 tons. To bring it within the prescribed limit, the fore wheels were made to serve in place of the larger pair, and their own place was filled by a still smaller pair. This engine was designed in almost every part, we believe, by Mr. Wellington Lee, formerly of New York. The boiler is upon Messrs. Lee and Larned's patent, consisting "of a central furnace surrounded by a shell of vertical water tubes $2\frac{1}{4}$ inches; around this is a steam chamber, which, in ordinary work, is filled with water to about one-third of its height; from this chamber depends a flat water-space, the connection being made with the steam drum by a series of $2\frac{1}{4}$ in. vertical tubes, a series of short $2\frac{1}{4}$ in. pass independently of

them through the suspended slab and steam drum respectively. A series of $\frac{3}{4}$ -in. tubes pass from the suspended slab to the water bottom, into which the bottoms of the outer tubes are secured. Made of gun metal and steel, in conjunction with best Lowmoor iron. The tube surface is 173 sq. feet, while the fire-box surface is 37 sq. feet. The quantity of water contained in the boiler is about 41 gallons, the steam-space being 11050 cubic inches." The framing is formed in a single forging of some difficulty and considerable ingenuity. There are two horizontal steam cylinders, the pistons working double-acting pumps of the same stroke. The arrangement, known as the duplex pump, is that of Henry R. Worthington, of New York, and has been patented by Mr. Lee in this country. The steam cylinders are $9\frac{1}{2}$ in. in diameter, the pumps, during the trial, being of $6\frac{1}{2}$ in. bore, although they may be changed in about twenty minutes, to a bore of $5\frac{5}{8}$ in., where greater forcing power, irrespective of volume, is required. The engine is fitted and intended to work with either of these two sizes of pumps, as the particular nature of the work may require. The stroke of the pistons is $8\frac{1}{2}$ to 9 in. With the "duplex pump" no crank shaft is required, the piston rod of one engine working the valve of the other, while separate steam and exhaust ports are employed, and both pistons completely cushioned by compressed steam at both ends of the cylinder. The ordinary working speed is 150 double strokes per minute, but the engine has been driven (not on the present trial, however) at upwards of 350 double, or 700 single, strokes of each piston. This was with the $5\frac{5}{8}$ in. pumps, the ratio of steam to water with this size being as 2.85 to 1, while with the $6\frac{1}{2}$ in. pumps the ratio is 2.136 to 1, the area of piston rods not being taken into account. On a private trial of this engine a plate was placed across the mouth of the air vessel, shutting off the access of water to its interior. The engine could not thus be driven up to its full speed, nor was the jet very steady, yet it was very much more so than would have been supposed.

Mr. Roberts' engine weighed 39 cwt. 1 qr. 4 lbs., "and thus, although apparently intended originally as a competitor in the class of $1\frac{1}{2}$ ton engines, had to work against those of 3 tons. It has a boiler, the body of which is 30 in. diameter, 2 ft. deep, of best iron full $\frac{5}{16}$ in. thick, tube plates are bare $\frac{1}{2}$ in. thick.

The fire-box is formed of a circle of 29 vertical water tubes 1 in. in diameter and 2 ft. long, these being surrounded by a thin sheet iron casing, while the body of the boiler contains 248 tubes $\frac{3}{4}$ in. in diameter and $19\frac{1}{2}$ in. long between plates. The whole tubular surface is 118 square feet, the fire-box surface being 23 feet. The quantity of water contained in the boiler is $12\frac{1}{2}$ gallons, the contents of the steam space being 6597 cubic inches. The cylinder is single and vertical, 7 in. in diameter with 13 in. stroke, with a cross-head and side rods working down to one end of a bell crank, from which is worked one of Mr. Roberts' patent double bucket pumps, $9\frac{1}{2}$ in. in diameter, and with a motion of $3\frac{1}{8}$ in. on each bucket, one double stroke of the steam piston thus clearing a cylindrical water space $9\frac{1}{2}$ in. in diameter and $6\frac{1}{4}$ in. long. The suction and delivery valves of the pump are of india rubber, having an area of 12.17 in., and a lift of $\frac{1}{2}$ in. The suction pipe is 4 in. diameter, the hose in use $2\frac{1}{2}$ in. diameter. From the bell crank a connecting rod drives a small fly-wheel, the shaft of which carries the eccentric for working the slide valve. The framing of this engine is of light angle and strap iron. The boiler is fed by a pump, a small injector not having been found to work well. The main suction and delivery valves are connected, by Mr. Roberts' regulating apparatus, so that the smallest possible streams—less than $\frac{1}{16}$ th inch in diameter—may be thrown if required.

The engine Victoria, entered by Messrs. Butt and Co., was made by the Amoskeag Manufacturing Company, of Manchester, New Hampshire, U.S. Its weight is understood to be 6,100 lb. The boiler is upright, with 313 fire-tubes, $1\frac{1}{4}$ in. outside diameter, and presenting $183\frac{1}{4}$ square feet of heating surface. The fire-box has $16\frac{1}{2}$ square feet, the smoke-box is submerged, the water level being above it. The boiler is $36\frac{3}{4}$ in. in diameter, and 5 ft. 5 in. high. Its water space is given as 10 cubic feet, or $62\frac{1}{2}$ gallons, while the steam space is $8\frac{1}{2}$ cubic feet. The framing of the engine is a hollow gun-metal casting, serving as air vessels, water passages, &c. The fore wheels cannot fore-lock, and this remark applies to all the American engines, although it was formerly the custom in the States to fore-lock the wheels. The single vertical steam cylinder is $10\frac{1}{2}$ in. in diameter, the piston of 12 in. stroke working directly a

double-acting pump of 6 in. bore, the ratio of steam to water being as 3.06 to 1. The ordinary number of strokes was given as 200 per minute. The suction and delivery valves are of india rubber, numerous and large, giving the same area as the bore of the pump. The lift is $\frac{1}{4}$ in. The finish of this engine, as that of all the American engines, was of a superior kind, even after making due allowance for its showy and rather *bizarre* character.

The Alexandra, entered by Messrs. Lee and Co., is by the same makers, and is of the same general construction as the Victoria. The weight is given as 3,100 lb., the boiler 27 in. in diameter, having 199 vertical fire tubes, $1\frac{1}{4}$ in. in diameter, and presenting $97\frac{1}{4}$ square feet of surface. The fire-box has $9\frac{1}{2}$ square feet of surface, and the submerged smoke-box $9\frac{1}{2}$ square feet, water space 4.23 cubic feet, steam space 4.32 cubic feet. The single steam cylinder has a bore of $7\frac{3}{4}$ in., the piston of $9\frac{1}{2}$ in. stroke, working a double acting pump, $4\frac{1}{4}$ in. bore, and of the same stroke, the ratios of steam to water being as 3.33 to 1. The ordinary working speed of this engine is given as 300 revolutions per minute, the steam pressure in all the American engines being about 100 lb. Both this engine and the Victoria have slotted cross-heads and fly-wheels.

The Manhattan is of the same general construction as that exhibited last year by Mr. Lee in the nave of the International Exhibition. The dimensions are larger, however, and the weight, 5,300 lb., correspondingly greater. The boiler is of the same construction as that of Messrs. Easton, Amos, and Sons' engine, having 243 tubes, a part of which are $2\frac{1}{4}$ in., and the others $1\frac{1}{2}$ in. in diameter, the lengths varying from 3 in. to 4 ft., the tube surface being $133\frac{1}{2}$ square feet, the fire-box surface $48\frac{1}{2}$ square feet; the total heating surface in contact with water and steam being 182 square feet. The water space is 38 imperial gallons, steam space $7\frac{1}{4}$ cubic feet. The diameter of the boiler is 36 in., and its height 5 ft. 5 in. The single horizontal steam cylinder is 9 in. in diameter, the piston having an $8\frac{1}{2}$ in. stroke, and working a rotary pump up to 400 revolutions per minute."

Messrs. Gray and Sons' engine weighed 38 cwt. 1 qr. 4 lbs. The principal feature of this was the boiler, which is a cylinder

30 in. diameter 26 in. long. Slowly revolving over the fire-grate on two trunnions fired at its ends, and containing 28 iron tubes, of 2 in. external diameter, and 28 ditto, $1\frac{1}{2}$ in. ditto; the shell is of steel plates, $\frac{1}{4}$ in. thick, and ends of ditto are $\frac{1}{2}$ in. Lowmoor. The boiler is enclosed in iron casing lined with fire-clay. This arrangement was lately patented by Dr. Grimaldie, which patent, by the way, is not very valid, seeing the very same arrangement was patented many years ago, and an illustration is to be found of it in some of the back volumes of the '*Practical Mechanics' Journal*.' The engine has a steam cylinder of $9\frac{1}{8}$ in. diameter, the water cylinder being 7 in. diameter, both having a stroke of 8 in., the pump being double-acting.

In the foregoing description of the different engines, excellent examples are to be found of boilers of comparatively large power, and occupying little space, being at the same time capable of standing high-pressures and embodying little weight. In many cases homogeneous metal has been the material employed, and so far with good results.

Proceeding now, however, to the results of trial.

LARGE CLASS.

FIRST TRIAL. (For 2d Trial see p. 218).

Delivering 1,000 Gallons into a Tank at a true distance of 67 ft. and 27 deg. from the horizon. The water in the Boiler being Cold when the signal was given to commence; each Engine commencing to work on attaining a Steam Pressure of 100 lb. on the square inch.

No.	Names.	Time of raising steam to 100 lb.	Time of filling tank.	Total.	REMARKS.
		min. sec.	min. sec.	min. sec.	
1	Easton and Amos,	13 14	6 16	19 30	{ Began to work at 100 lb., fell directly to 40 lb., and continued so through- out; stopped, and steam rose to 130 lb. { Suction pipe choked, left off working about 2 min.
2	Merryweather,	10 25	9 7	20 7	
3	Shand and Mason,	10 51	12 19	23 10	
4	Butt and Co.,	16 30	6 48	23 18	
5	Roberts,	11 40	20 24	32 4	

Delivering into Large Tank.

No.	Names.	No. of trial.	Time.			No. of deliveries open.	Length of hose.	Size of nozzle.	Depth from which water is drawn.	Horizontal distance in feet.	Vertical height in feet.	True distance in feet.	Angle from horizon.	Average steam pressure.	Average water pressure.	No. of gallons delivered.	Time of raising steam.
			Hour.	Min.	Sec.												
1	Merryweather,	1	1	24	55	2	440	1½	ft. in. 16 4	40	40	56	deg. 45	91	89	16,086	m. s. 10 32 to 80 lb.
2	Shand and Mason,	1	2	0	0	2	440	1½ & 1½	16 4	40	40	56	45	96	62	12,917	m. s. 11 21 to 120 lb.
3	Roberts,	1	2	0	0	1	420	1½	16 4	40	40	56	45	75	75	9,986	m. s. 11 20 to 80 lb.
4	Batt and Co.	1	0	46	50	2	440	1½	16 4	40	40	56	45	78	78	8,280	m. s. 14 10 to 45 lb.
5	Easton and Amos,	1	1	32	35	2	440	1½	16 4	40	40	56	45	98	41	3,036	m. s. 12 30 to 90 lb.
6	Nicol (Manhattan),	1	0	4	55	2	420	1½	16 4	40	40	56	45	0	0	None.	m. s. 13 9 to 45 lb.

REMARKS.

1. Fire lighted 4.1m. 55s., gauge moved at 4.8m. 20s., engine started at 4.12m. 27s., water drawn in about 10 revolutions, pumps not primed, valve box leaked slightly, and engine worked satisfactorily in every respect.

2. Fire lighted 11.25m. 46s., gauge moved at 11.32m. 53s., engine started at 11.37m. 7s., pumps primed at 11.45m. 48s., drew water at 11.47m., water first through nozzle 11.48m. 59., in hood at 11.49m. 19s., shifted nozzle, $3\frac{1}{4}$ minutes delay. High wind.

3. Fire lighted at 11.17m., started engine at 11.28m. 20s.

4. Fire lighted at 5.55m. 10s., started engine at 6.9m. 20s., repeatedly stopped from slide valve not acting, and stopped entirely at 6.46m. from cylinder cover breaking.

5. Fire lighted at 2.2m. 35s., gauge moved at 2.10m., started engine at 2.15m. 5s., pumps primed, worked till 2.54m. 5s., stopped to shift plungers, went to work again, and stopped entirely at 3.35m. 10s., from two fire-bars falling out.

6. Fire lighted at 10.51m. 14s., gauge moved 10.59m. 20s., drew water directly, steam up to 140 lb., at 11.8m. 45s. stopped two minutes, started again, made a few revolutions, and fly-wheel broke.

SECOND TRIAL. (*For Table of 1st Trial see p. 216.*)

Delivering 1,000 Gallons into Tank at same Distance, commencing with full Steam.

No.	Names.	Steam at beginning.	Steam during trial.	Time of filling tank. min. sec.	REMARKS.
1	Shand and Mason,	100		3 0	Not filled.
2	Butt and Co., ...	100		3 3	
3	Merryweather, ...	145		3 7	
4	Roberts, ...	80		12 30	
5	Easton and Amos,	—		— —	

Vertical Jet against Tower.

FOURTH TRIAL.

No.	Name.	Size of jets.	Greatest height thrown.
2	Shand and Mason	$1\frac{1}{8}$ in.	180ft.
3	ShandMerryweather	$\frac{7}{8}$	180
4	Butt and Roberts	$\frac{1}{2}$	150
5	Roberts, and Co.	$\frac{3}{4}$	55

REMARKS.

The nozzle was in each case selected by the proprietor of the engine under trial.

GRAY'S ENGINE:—Lighted fire at 7.m.40s.; steam, 9 lb. at 7.17m.; got to work at 7.23m. 40s to blow fires; 7.27m., water through hose; owing to some of the pipes connected with the steam gauge breaking, no further trial could be made. This engine was fitted with Grimaldi's revolving boiler.

SMALL CLASS.

Delivering 1,000 Gallons into a Tank at a true distance of 56ft., and 45 deg. from the horizon. The water in the Boilers being Cold when the signal was given to commence; each Engine commencing to work on attaining a steam pressure of 100 lb. to the square inch.

FIRST TRIAL.

No.	Name.	Time of raising steam to 100 lbs.		Time of filling tank		Total time.		REMARKS.
		min.	sec.	min.	sec.	min.	sec.	
1	Shand and Mason	11	36	5	24	17	0	{ Owing to a broken bolt there was great leakage in water cylinder.
2	Lee and Co.	11	55	6	3	17	58	
3	Merryweather.....	12	15	9	14	21	29	

Delivering 1,000 Gallons into Tank at same distance, commencing with Full Steam.

SECOND TRIAL.

No.	Name.	Steam at beginning.	Steam during work.	Time filling tank.		REMARKS.
		lb.		min.	sec.	
1	Shand and Mason	85		5	49	Leakage remedied.
2	Lee and Co.	125		5	50	
3	Merryweather	100		6	17	

Delivering into Large Tank.

THIRD TRIAL.

No.	Name.	Time.			No. of deliveries open.	Length of hose.	Size of nozzle.	Depth from which water is drawn.	Horizontal distance in feet.	Vertical height in feet.	True distance in feet.	Angle from horizon.	Average steam pressure.	Average water pressure.	No. of gallons delivered.
		Hour.	Min.	Sec.											
1	Shand and Mason.	1	0	0	1	420	in. 1 and 1½	16.4	40	40	56	deg. 45	146	80	8,142
2	Merryweather and Son.	1	0	0	1	420	½	16.4	40	40	56	45	86	45	4,885
3	Lee and Co.	1	0	0	1	420	¾	16.4	40	40	56	45	80	60	4,278

REMARKS.

1. Steam ready at 150 lb., started at 7.3m. 32s., stopped at 7.12m. 5s. to put on an additional length of hose; worked well throughout.
2. Steam ready at 110 lbs., commenced work at 3.43m. 30s., pumps primed.
3. Steam ready, started at 2.1m.; worked well without any stoppage.

The prizes awarded were as follows:—

LARGE CLASS.

Messrs. Merryweather and Son, first prize	£250
Messrs. Shand, Mason, and Co., second prize	100
Mr. W. Roberts, highly commended.	

SMALL CLASS.

Messrs. Shand, Mason, and Co., first prize	£250
Messrs. W. Lee and Co., second prize	100

As usual, in such trials as the above, much dissension arose, especially among those who *did not* get prizes. As to the accuracy of the tests and the discretion of the judges, it is not our purpose to enter into any arguments for or against such trials, preferring rather to let the facts speak for themselves, as they alone can be useful to engineers who may be interested in fire engine construction.

In concluding this division we append the following suggestions for improvement made by the '*Mechanics' Magazine*':—

"In the steam fire engine, more particularly when intended for service on land, we have a machine which must satisfy many strictly exceptional requirements. In order that it may be useful and admirable in the fullest sense of the terms, it must not only be extremely light and portable, but of enormous strength as well. Intended to work under the most trying circumstances, and at seasons when the calmest pulses are accelerated, and the coolest heads lose their self-possession, it must be prepared for rough work and much knocking about. Nothing but first-class workmanship and materials can reconcile these incompatibilities. Ere long, we trust to see steel take the place which wrought-iron now holds in the fire engine. It is already partially used, in the form of piston rods and crank shafts; and there is nothing to preclude its employment in the shape of boiler shells and carriage frames. In cylinders and pumps, the use of homogeneous metal or malleable cast-iron, would effect a very considerable reduction of weight, and positively add to their powers of endurance. The principle of annealing articles of cast-iron required to sustain great strains, is better understood daily; and a steam cylinder or pump valve, one-fourth of an inch thick, so treated, is stronger than one of twice the weight left as it comes from the moulder's

flask. By these means alone, we do not doubt that an important reduction might be effected in the weight of future engines; whilst improvement in the arrangement of the working parts, frames, and trusses, would permit a more equable distribution of the strains to which the machine is exposed, and materially add to its longevity.

"The principles involved are simple enough. In their adaptation to the requirements of practice lies the difficulty. Steam gives out its useful effect equally well, whether a piston moves fast or slow, so long as economy of fuel is not an object of desire. Hence, if weight were not a consideration, the speed of the engine would be a matter of slight importance, and that velocity best adapted to the description of pumps employed, could be adopted without hesitation. In order to secure portability, however, in the highest degree, with a pressure kept within reasonable limits, quick-working engines are indispensable. This would, of course, entail no difficulty were the motion of water as manageable as that of steam. Unfortunately this is not the case; and, as a consequence, the steam fire engine requires to be treated more as an hydraulic than as a steam machine. We are, therefore, inclined to prefer that principle of construction which permits a long stroke of the steam, and a short stroke of the water pistons. Such an arrangement is, perhaps, more likely to secure a high co-efficient of useful effect in proportion to the fuel burned and the weight of the machine, than any other. High-speed engines coupled directly to the pumps, are quite capable of doing good service, as our American friends have showed; but we imagine, with a very considerable and unnecessary waste of fuel. Were it not for the effects produced by wear, the rotary pump, as adopted in the 'Manhattan,' would seem to be best of any; and it is quite possible that this objection may not be found insurmountable. Notwithstanding a bad boiler, the admirable qualities of that machine, in everything concerning the engine and pump, were sufficiently manifest. We believe that excellent results would be obtained from a similar arrangement supplied with steam by a generator, say on Mr. Field's principle, of sufficient power. The rotary pump, however, is condemned for the present by those best acquainted with *its* capabilities; and it is, therefore, unnecessary to dwell further

effectual remedy. If the centrifugal form is deemed objectionable, there are many others open to our adoption—a modification of Pitcher's governor, for instance, might probably be used with great advantage. These are, however, minor matters; and as we have good reason to be satisfied with the progress made in the last few years, we may safely leave this consideration, for the present, to those most interested. The necessity for a fly-wheel and crank-shaft is a more important question, on which great difference of opinion exists. We believe that its adoption simplifies the valve gear, gives steadiness to the motion of the engine, and permits a considerable reduction in the space occupied by the machinery—advantages not to be lightly sacrificed."

With regard to the working expenses of steam fire engines as compared with hand worked engines in America, the following is published by the Amoskeag Manufacturing Company:—

"In regard to the cost of running a steam fire engine many people have very wrong impressions, being led, by the reports of the cost of maintaining them in some large cities when they were first put into service, to suppose that the expense must be very great in all cases. In these cities a regular 'fire brigade' is employed, and the extinguishment of fires is a daily business, and the number of men necessary to work an engine are constantly employed and paid. But even here, as shown by the reports, the use of steam engines has reduced the running expenses of the fire department. But in cities of 25,000 inhabitants, more or less, where fires occur perhaps not oftener than once or twice in a month, the expense of maintaining a steam fire engine is very much reduced; in fact, a steamer in such a city can be run at a less expense per annum than the usual cost of maintaining a hand engine.

"In the city of Manchester, N.H., the fire department consists of three steam fire engines. We append below the expense of running these engines one year, taken from the city report, and the expense of running a hand engine for the same period. The cost of repairs is found by experience to be no greater on the steam fire engines than on hand engines. The first steam engine, which has been three years in service, has not required a cent to be expended upon it as yet.

"A steam fire engine company is composed of fourteen men, all told, one of whom, acting as a driver and steward, is constantly employed, remaining at the engine house with a pair of horses always ready to run out with the engine in case of an alarm of fire. The other members of the company have other employments, and turn out only on an alarm of fire.

STEAM FIRE ENGINES.

		Dols.
Amoskeag	Expenditures	864 32
Fire King,		855 78
E. W. Harrington,		496 09

"The above expense includes pay of members, team expenses, cost of gas, wood, coal, and all necessities incident to service.

"The E. W. Harrington is a second-class engine, stationed in the outskirts of the city, and was run cheaper from the fact that no horses were kept for it by the city.

"A first-class hand engine company is allowed to number, all told, fifty men, and the members of the company are paid as follows:—

FIRST-CLASS HAND ENGINE COMPANY.

	Dols.
1 foreman,	35 00
1 assistant foreman,	28 00
1 clerk,	28 00
1 steward,	68 00
46 men, at 18 dols. each,	828 00
50 men.	Total, 987 00

"By this it will be seen that in a city like Manchester, with 20,000 to 25,000 inhabitants, a first-class steam fire engine can be run at an expense not to exceed that of a first-class hand engine, while in service it will do at least four times the work.

"In the city of Boston, the comparative cost of running the two kinds of engines is as follows, viz. :—

STEAM FIRE ENGINE.

	Dols.
One engineer,	720 00
a fireman,	600 00
a faller,	600 00

STEAM FIRE ENG.] FIRE ENGINES AND TURBINES.

	Dols.
1 foreman of hose, ...	150 00
3 hosemen, at 125 dols. each, ...	375 00
7 men.	
Keeping of 2 horses, ...	315 00
Total, ...	2,445 00
Total, ...	315 00
Total, ...	2,760 00

HAND ENGINES.

1 foreman, ...	150 00
1 assistant foreman, ...	175 00
1 clerk, ...	125 00
1 steward, ...	125 00
3 leading hosemen, at 125 dols. each, ...	375 00
33 men, at 100 dols. each, ...	3,300 00
40 men.	
Total, ...	4,250 00 "

DIVISION FIFTH.

TURBINES.

THE following interesting and able article from the '*Mechanics Magazine*' will form an appropriate introduction to this department of the work :—

"The class of water-wheels, known by the general term 'turbine,' supplies us with, perhaps, the most practically perfect means to be met with in the arts, of obtaining the highest results from given mechanical effects. To all intents and purposes, the turbine is, if properly constructed, a perfect motor, capable not only of working under all sorts of circumstances and under the most variable conditions, but of invariably giving out a high coefficient of useful effect as well. Perhaps invented, at all events first rendered effective and economical by Fourneyron, in 1837, it has gradually worked its way into general favour solely by its own merits. It is not easy to say how many of them are at work in Great Britain at the present moment. Messrs. Williamson, Donkin, Schiele, the North Moor Foundry Company, and many other firms, have, we believe, full employment found them in their construction; while abroad their use is even more extended than it is here in the fatherland of the steam-engine—

the giant who will scarcely brook the presence of a competitor within his domains. In France and Germany, the turbine enjoys great favour; the comparatively high price of fuel acting to some extent as a bar to the habitual use of steam machinery. In America, the ordinary vertical water-wheel was exclusively employed—the breast-wheel being considered best—until 1844. In 1843, Mr. Elwood Morris communicated to the Journal of the Franklin Institute, a translation of Morin's experiments on turbines, which attracted considerable attention. The year after, Mr. Boyden, an engineer experienced in the manufacture of hydraulic machinery, designed and constructed a horizontal water-wheel for the Appleton Company's mill, near Lowell, in Massachusetts, which at once embodied several improvements on the Fourneyron arrangement, and may be regarded as the first instance of this application of water-power in the States. In 1846, the same gentleman constructed three turbines, of about 190 horse-power each, on the same general principles; the particular design being somewhat modified and improved. It is said that the mean maximum effect of two of these was found, by careful experiment, to equal 88 per cent. of the theoretical power due to the fall—a statement which, probably, contains a slight exaggeration. The general principles and mode of formation which distinguish the Fourneyron wheel are so well understood that it would be superfluous to dwell on them individually at length. The water, distributed in horizontal jets by peculiarly curved vanes or guides, issues from the circumference of an inner fixed wheel, composed of two discs kept apart by the guide plates, and passing through an outer annular wheel, fitted also with guides of a contrary curvature, puts it in motion; its interior periphery revolving as nearly as possible in contact with the exterior periphery of the inner or guide wheel. This is the Fourneyron turbine in its simplest form. One of the most important improvements effected by Mr. Boyden, was the application of the 'diffuser,' almost universally adopted since. The invention is embodied in the formation of two large stationary discs without and around the wheel, the space between which at the inner periphery is very little greater than that between the crowns of the wheel at the part next to them. These discs curve apart and outward, so that the space at their exterior

periphery is twice as great. The section through which the water passes in escaping from the wheel is thus enlarged in the ratio of one to four; hence its action should fall from 1 to 1-16th in the same distance, provided the wheel be submerged. The effect of this arrangement is to reduce the pressure on the escaping water, and thus increase the power as though the fall were increased. The theoretical gain to be derived by this arrangement is equal to about 5 per cent. on the whole power; though from one cause or another only 3 per cent. is usually realized. Mr. Boyden suspended his turbine from above, and was the first to point out the expediency of employing very thin guide-plates and vanes. One of the greatest objections to the Fourneyron wheel and its modifications is, that, being always submerged, it is, to some extent, inaccessible for repairs or examination. It is frequently far from convenient to drain away the water, especially when more than one turbine is supplied from the same race. As early as the year 1838 this objection was recognized, and the 'Jonval' wheel introduced to obviate it. Instead of revolving outside the stationary guides, the buckets in this turbine revolve below them. Both the fixed and moveable wheels are placed within a tube of sufficient diameter, the orifice of which, placed below the level of the water in the lower race, is so contracted as to allow of only the proper quantity of water passing through, due to the velocity arising from the difference of the two levels above and below the turbine. By this arrangement the wheel may be placed in any part of the height of the fall deemed most desirable; the necessary force and velocity of the water being obtained by the pressure of the atmosphere on the upper surface of the suspended liquid column. When the supply of water is cut off by closing the upper sluices, the wheel is left high and dry for repairs, as the tube is usually large enough to afford ample space for a man to work in it with ease.

"When the turbine is employed to render high falls available, the foot-step of the vertical spindle often gives much trouble, as well from the difficulty of lubricating it properly, as from the great weight which it has to sustain, and the high speed at which the shaft revolves. At St. Blasier, in the Black Forest a wheel only 13 in. in diameter is put in motion by a column of water 354 ft. high. Whether all the pressure due to the

vast height is rendered available or not, we cannot say. The wheel makes 2,200 revolutions per minute, driving 8,000 water spindles, with the necessary machinery for slubbing, roving, &c. Fifteen hundred revolutions per minute are by no means uncommon with larger wheels. Mr. Boyden, in America, and Mr. Mallet, in this country, cut the Gordian knot by hanging the revolving ring and its shaft, and all the weight of water upon it, from a ring of conical rollers above the pen-trough, running between two faced-up iron plates, the central toe or step being used merely as a steadier. When the foot-step is retained, the best practice is to form a cavity in the end of the shaft, which is fitted accurately to a hardened steel pin, projecting upwards, firmly fixed in the base of the wheel pit, on which the entire weight is sustained. The proper shape for this pin and its corresponding cavity has been made the subject of much mathematical disquisition. Oil is usually supplied through an aperture drilled up the centre of the pin, by a very small force-pump, put in motion by an eccentric on some slow running shaft in the mill above. In the great Fairmount Jonval turbines, intended to supply water to the city of Philadelphia, the central shafts are supported on stout cast iron columns, bolted down to the iron bottom of the draft box or vertical tube. A socket, resting on the top of this column, contains a circular block of lignum vitæ, 15 in. in diameter and 8 in. or 9 in. thick. Its upper surface is rounded to a partially spherical shape, and a few spiral grooves are cut in its surface to permit the entrance of water, and thus secure constant lubrication. A cast iron socket, hollowed out to fit this block, is keyed on the lower extremity of the vertical shaft, thus forming the bearing. These wheels are, perhaps, the largest of the kind in the world, being not less than 9 ft. in diameter over the buckets; each wheel, we believe, drives a nearly horizontal double-acting pump, 18 in. in diameter, and 6 ft. stroke, intended to make twelve double strokes per minute when pumping against the head of water in the reservoir.

"The construction of the turbine suggests some of the most complicated problems in hydraulics, and theory scarcely yet affords the means of solving them. Practice alone supplies us with thoroughly trustworthy results. From this reason, there is *little doubt* that the statements of the usual effect realized from a

given fall are frequently over-estimated, the quantity of water passing through the wheel being really in excess of that assumed from calculation. Still, making every allowance, there is no doubt that with proper care turbines usually give out a higher coefficient of useful effect than perhaps any other moving power in existence. At first sight, it appears that the entering water should impart a severe shock to the curved buckets which oppose its motion. This disappears, however, when the wheel moves at a proper velocity. Under correct arrangements, the water enters the wheel without impact, and passing along the whole length of the blades which constitute the buckets, and exercising a pressure at every part, whereby its velocity is constantly reduced, while the direction of its motion is modified by their curve, it finally leaves the wheel with an insensible motion, being deposited as it were in the tail race, from which it flows in obedience to the law of gravitation at a velocity determined by the inclination of the floor on which it rests. In order to secure this action, the most extreme accuracy of workmanship is absolutely essential. It is useless to set out the proper curves with a strictly mathematical precision, if these are afterwards departed from by an erroneous method of practical construction. Theoretically, the guide curves should have no thickness; and although this desideratum is unattainable, we can, at all events, approach almost indefinitely near to it. It is not easy to secure the necessary accuracy of fitting through all the details, by hand labour. The more extended use of machine tools specially designed to carry out the end in view, and of cast steel as a material of construction, may do much to reduce the first cost and improve the performance of the turbine; the latter imparting that stiffness and strength which cannot be obtained from the use of sheet-iron. It is impossible to over-estimate the importance of correct form, and it requires little reflection to show how easily thin guide plates may be deflected by the pressure of the water when the wheel is at work, although, when at rest, their shape may leave nothing to be desired. Machine tools would rapidly and cheaply impart that smoothness of surface and delicately beautiful curvature to the guide plate and buckets, on which the efficiency of the machine almost wholly depends."—*'Mechanics' Magazine.'*

The following article on turbines and the friction of water in the various parts of a turbine appeared in the '*Engineer*:'—

"In the case of a small supply of water with considerable fall—a case in which the advantages of a turbine over any other motor are becoming better understood every year—it is necessary to bring the water down to the turbine through a pipe. If there is a supply of, say, 400 cubic feet of water per minute, an unprofessional man is apt to suppose that only a pipe capable of discharging that quantity of water is required. An engineer is well enough aware that a large allowance must be made for the friction of the water in the pipe, but the exact determination of the discharge and loss of head due to friction is not always easy, even to those whose pursuits really require that they should be thoroughly conversant with such matters. Professional men, therefore, who so well know the paucity of elementary scientific knowledge among those who delight in calling themselves 'practical men,' will readily pardon the introduction and application here of the rules for estimating the flow and friction of water in pipes. Eytelwein's formula for the flow of water in pipes at their full discharge is as follows—

$$\frac{2356 \sqrt{d^5}}{\sqrt{l+50} \frac{d}{h}} = \text{discharge}$$

in cubic feet per minute, l , h , and d being, respectively, the length, fall, and diameter of the pipe in feet. Where the length is considerable the divisor may be taken as $\sqrt{\frac{l}{h}}$, the

50 diameters allowed for bringing the water 'into train' being disregarded. The square root of the fifth power of the diameter of the pipe will be quickly found by those in the habit of referring to a table of logarithms, and to those who are not, the calculation itself is not necessarily very tedious. It will save time, in many cases, to remember that, for a pipe 1 ft. in diameter, the square root of the fifth power is 1, and to make a note that, for a pipe 6 in. in diameter it is 0.177 nearly; for a pipe 18 in. in diameter 2.755, for a pipe 2 ft. in diameter, 5.657; 3 ft., 15.585; and 4 ft., 32. Thus, to find the discharge of a long pipe, in

cubic feet per minute, the square root of the fifth power of the internal diameter in feet is multiplied by 2356, and the product is divided by the square root of the quotient obtained by dividing the length by the fall. Mr. Beardmore's valuable *Hydraulic Tables*, published by Messrs. Waterlow, contain a table of constants, by Mr. James Leslie, C.E., from which the discharge may be still more readily obtained. If we take for illustration a 1-ft. pipe, 500 ft. long, and falling 20 ft. in that distance, we shall find the discharge to be, by the formula already given, 471 cubic feet per minute. This discharge, on a 20-ft. fall, would, were there no loss from friction, correspond to 17·8 horse-power, of which about 14 might be counted upon in practice with a turbine. But 471 cubic feet of water discharged per minute through a 12-in pipe must move

$$7854 : 1 :: 471 : 599\cdot7 \text{ ft.}$$

per minute, or, say 10 ft. per second, and the friction due to this velocity must be allowed for before the available power can be known. The formula generally adopted for estimating the friction of water in pipes is that of Wiesbach, and is as follows:—

$$H = \left\{ 0\cdot0144 + \frac{0\cdot01716}{V\sqrt{V}} \right\} \frac{L}{D} \times \frac{V^2}{64\cdot4}$$

“From this formula Professor Thomson has computed a table showing the friction of water in pipes of different diameters and 100 ft. in length, at velocities ranging from 1 to 7 ft. per second. The last named velocity is, perhaps, the highest practically met with in pipes; but, in the case already assumed, the velocity is greater than is provided for in Professor Thomson's table, and we must apply the formula; H being the head required to overcome the friction, L the length of the pipe, D the diameter, and V the velocity per second, all in English feet. The head due to friction will be found to be 15·36 feet, leaving but 4·64 ft., or less than 4 ft. 8 in. of the whole head of 20 ft., available for driving a turbine. Thus the whole theoretical power obtainable from the water discharged through a pipe 500 ft. long, 1 ft. in diameter, and having a fall of 20 ft., would be but 4·1 horse-power, of which a turbine would give only about 3 horse-power. We may mention, while upon this subject, that the theoretical horse-power of a stream is most readily obtained by multiplying the

number of cubic feet of water delivered per minute by the effective fall in feet, and dividing the product by 529. The power practically obtainable with a good turbine will be found by dividing the product (obtained as just described) by 700, corresponding to an efficiency of about 76 per cent.

"We have thus seen that, if a pipe be allowed to deliver at its full discharge, very little power will remain in the water at the point of delivery. Indeed, without calculating the actual loss of head due to friction, it is only necessary, in the case assumed, to find the head corresponding to the velocity at which the water is discharged from the pipe. This is 10 ft. per second, for we have seen that the flow through the pipe is at the rate of 599.7 ft. per minute. The height in feet corresponding to this velocity will be obtained by dividing it by the velocity due to 1 ft. of fall, and taking the square of the quotient. The actual velocity of water falling in the air from a height of 1 ft. is about 5 ft. per second, and $\frac{10}{5} = 2$, which, squared, gives 4 ft. as the head corresponding to a velocity of 10 ft. per second. This result is doubtless very near the mark, and when the pipe was discharging up to its full capacity about 4 ft. of the whole fall of 20 ft. would be the most that could be counted upon for the purposes of a water wheel.

"Let us, now, assume that an 18-inch pipe is employed with the same length of 500 ft., and a fall of 20 ft. If the supply of water were sufficient, this pipe, having $2\frac{1}{4}$ times the area of one of 12 inches in diameter, would discharge 2.755 times as much water, the square root of the fifth power of 1.5 being 2.755, while that of 1 is 1. Thus, the 18-in. pipe would discharge 1297.6 cubic feet per minute, and at a lineal velocity of 12.24 ft. per second. But as we are dealing with a supply of water equal only to the full discharge of a 12-in. pipe, or 471 cubic feet per minute, this, in an 18-in. pipe, would move with a velocity of 4.44 lineal feet per second, and the head requisite to overcome the friction of the water in the pipe at this velocity would be 2.3 ft., leaving 17.7 ft. available fall. With a 2-ft. pipe the velocity of flow would be but $2\frac{1}{2}$ ft. per second, and the loss of head but .6125 ft., or less than $7\frac{1}{2}$ in. in 20 ft.; but the saving of 1.7 ft. of fall might not, perhaps, compensate for the difference of cost between 500 ft. of 18-in. pipe and the

same length of 2-ft. pipe, the difference of weight, with $\frac{1}{2}$ -in. metal in the pipes, being 7 tons, and the difference of cost being therefore from £30 to £40. The saving of 1.7 ft. additional fall would, with 471 cubic feet of water per minute, correspond to a gain of upwards of 1 actual horse-power, and in many situations this would be more than an equivalent for the interest upon the additional weight of pipes. In cases where the water can be brought down a vertical pipe for the whole height of the fall, the difference in weight between a large and a small pipe is of little practical importance; and in such a case a pipe of at least four times the sectional area of that which would just discharge the given quantity of water should be employed."

The following letter, addressed to the '*Engineer*' by the well-known makers of "Vortex or Whirlpool Turbines," Messrs. Williamson Brothers of Canal Ironworks, Kendal, was called forth by the above article:—"We beg to submit a few remarks, having reference to the article on Turbines, in your paper of 5th inst., and shall feel obliged by their insertion in your next publication.

"In regard to the angle formed by the extremity of the vanes, or buckets, with a tangent to the circumference of the wheel, you observe that, in outward-flow wheels, an angle of 20 deg. is adopted, and that one author prescribes 10 deg.; and you add that, in Thomson's inward-flow wheel, the corresponding angle is from 30 deg. to 45 deg., and that, consequently, a considerable part of the power is lost.

"In reply to this we may state that the maximum angle which occurs in Professor Thomson's wheel, constructed according to the formulæ prepared by him, is less than 30 deg., and that in large wheels it will be little above 20 deg.; certainly the average does not exceed 25 deg. But you omit altogether a very important consideration, which materially affects the amount of work carried away in the water leaving the wheels, namely, that in the vortex the water and wheel, at the point of discharge, are moving with velocities greatly below those which they have in the outward flow turbine. It is the excessively rapid motion of the wheel at the discharging ends of the vanes, or buckets, in outward-flow turbines, that renders a very small angle necessary or advisable in them, in order that the water may be shot back quietly enough

without the communication of a very prejudicially great radial velocity to the water on its leaving the vanes. But, on the contrary, in the vortex, the wheel has so little rotatory velocity at the inner, or discharging, ends of the vanes, that the water does not require to be shot backwards rapidly; and while the radial component of its motion relatively to the wheel is small, the proper tangential component is also small, and thus a larger angle for the inner ends of the vanes is perfectly admissible and proper. There would be no difficulty in diminishing the angle in the vortex, if that adopted were not as perfectly good as could be desired. To make it smaller we would only require to increase somewhat the depth of the wheel at the inner ends of the vanes.

"The following is an example, in the simplest form, of the effect of this difference in the velocities at the points of discharge in the two wheels. The velocity of the outer circumference of the Fourneyron turbine, where the water leaves the ends of the vanes, may be fairly taken for this comparison as equal to that due to the whole fall, while the like velocity in the vortex will be that due to one-eighth of the fall (since the inner circumference where the water leaves, in the latter, revolves only at half the speed of the outer circumference, which, again, has the velocity due to half the fall). Practically the actual working velocities would be arranged somewhat less to allow for the practical effects of resistances of friction, &c.; but as the modification would be applied to both wheels, it is unnecessary to take it into account here.

"If, then, we suppose an outward-flow turbine in a fall of 20 ft., and that its outer circumference is running with the velocity mentioned $= \sqrt{2 \times 32.2 \times 20} = 35.87$ ft. per second, and that the angle formed by the ends of the vanes with the tangent to the outer circumference be the extremely small one of 10 deg.; also that the water is sent backwards, so that the tangential component of its motion (relatively to the wheel) be exactly equal to the velocity with which the wheel moves forward (theoretically the condition of maximum effect), then the absolute velocity of the water will be $V \tan. \alpha = 35.87 \times \tan. 10 \text{ deg.} = 6.325$ ft. per second, and the loss of head corresponding thereto $= \frac{6.325^2}{2g} = 0.621$ ft. With the vortex, the velocity forward of the wheel and backward of the water will be $\sqrt{64.4 \times 2\frac{1}{2}} = 12.68$

ft. per second, and with the average angle of 25 deg., the velocity retained by the water = $12.68 \times \tan. 25 \text{ deg.} = 5.912 \text{ ft. per second}$, and the loss of head corresponding = 0.542 ft. Thus, taking the unusually small angle in the outward flow wheel, and the average one actually used in the vortex, the amount of work carried away in the water leaving the latter is less than in the former. Besides which, we have, in the vortex, the advantage of a better formed orifice.

"Turning to Professor Rankine's work on Prime Movers, and applying his formulæ for turbines to the supposed case, we find the results to differ only very slightly from those which we have shown. Professor Rankine gives, in the above work, a table of angles which may be used for various turbines with corresponding effect; for the outward flow wheels the two lowest he mentions are $14\frac{1}{2}$ deg. and $18\frac{1}{4}$ deg., and the angles he assigns for the vortex, with the same loss in the final velocities, are 36 deg. and 43 deg. respectively.

"In regard to the paragraph you quote (which is, though not quite accurately copied, from a notice by William Thomson, Professor of Natural Philosophy in the University of Glasgow, and not the inventor of the vortex) we cannot see that it presents any difficulty. It points out the important fact that, in the turbines of Fourneyron and Poncelet, the water has communicated to it a much higher velocity than in the vortex, where the maximum is approximately that due to half the fall; whereas, in the Fourneyron wheel, it necessarily attains the velocity due approximately to the whole fall, usefully applied, and in many examples of reaction-wheels much higher velocities are imparted to it. As the losses from friction, &c., increase as the square of the velocity, a reduction such as is effected in the vortex is of great importance.

"We will now refer briefly to the question of the efficiency obtained with the outward flow wheel, and we give the following quotations from Weisbach and Bühlman, who have probably more completely examined the principles of the turbine than any other writers on the subject.

"Weisbach writes:—'These recipients of water power are in many respects admirable machines; but to suppose that an efficiency = 0.85 to 0.90 has been obtained from them, arises from

some mistake.' After enumerating the various losses from friction, &c., which he estimates together to amount to 24 per cent., he proceeds:—'There remain only 76 per cent. of useful effect, and therefore a turbine that gives an efficiency of 0.75 may be considered as a very excellent one. The experiments of Morin, and other impartial persons, give results as to efficiency as high as 0.75, but never above this.'

"Bühlman writes:—'It is now fully admitted that Fourneyron deceived himself in supposing that these wheels economized 80 per cent., and more of the total available force. But the latest and fullest experience has shown that they economize certainly from 60 to 70 per cent., when those precautions are taken which should be attended to in their formation.'

"De Lacolonge considers that, as leaving a margin for deterioration in the turbine after working some time, 65 per cent. may be prudently taken, 'notwithstanding,' as he says, 'the results presented by some lightly made experiments showing figures of 0.79, 0.80, and even more, and the assurances of some inventors possessed of more imagination than information.'

"We might multiply such instances of the opinion of those best informed on the subject; but instead of this we will give the results obtained by various experimenters on the Continent, including Redtenbacher, Morin, Dieu, Daugny, and others. The efficiencies for fifteen different wheels (the majority made by Fourneyron himself) are the following:—One gives less than 0.6; seven between 0.64 and 0.70; five between 0.70 and 0.75; one 0.77; and one 0.79. The correctness of the last appears to have been afterwards found to be doubtful by Morin, who made the experiment. All these are given as maximum results, and the average for the fifteen turbines is 0.699.

"Of experiments made in America there are published in detail, we believe, only those by Mr. Francis, at Lowell, and those by the engineer of the Fairmount Waterworks, Philadelphia. Of the former we may say that, from the apparent care and completeness with which they were carried out, it is probable that their results are not far from the truth. But they do not give an efficiency greatly exceeding the approximate calculation of Weisbach, although the wheel tested was of very large size, new, of good workmanship, and in a moderate fall, and with

its best speed experimentally ascertained; in fact, with every condition in its favour. Yet the maximum efficiency obtained is 0.79375; and, by the way, there are in the same book experiments exactly similarly conducted on an inward-flow wheel, which gives a slightly higher result, namely, 0.79753. Thus the highest efficiency shown by Mr. Francis is obtained from an inward-flow wheel, which, we may add, is demonstrably inferior to the vortex.

"As to the Fairmount experiments, the apparatus employed for ascertaining the fall, the quantity of water used, and the work done, are not such as to give trustworthy results, especially in the short time allotted to each trial. Each experiment lasts from twenty to thirty seconds, during which a weight is raised to a height of 25 ft.; on the cord which lifts the weight are tied two pieces of tape, 25 ft. apart, and an observer notes the time at which the first passes a given point (the turbine having previously attained its proper speed), signals to an assistant to direct the water from the turbine into a measuring trough, and when the second tape passes, again signals for the water to be stopped, notes the time, and the experiment is complete. An error of one second in the time of admission to, or stoppage of, the water from the trough will alone make a difference of 4 to 5 per cent. in the result. Although the most important errors do not necessarily appear in the recorded results, yet even in these, the almost constant variations of the quantity of water used, and of the time occupied, in repetitions of experiments, where they should be identical (because the weight raised, the height of lift, and the fall of water on the wheel are given as unaltered throughout), abundantly prove the existence of error. Certainly these experiments cannot be held as authoritative against the unanimous testimony of the numerous eminent scientific men who have, in Europe, investigated the question of efficiency by rigid trials, and also by the application of the general principles of hydraulic science."

In answer to the foregoing letter, the following appears in the '*Engineer*':—

"A letter appears in another column in defence of the so-called 'vortex wheel.' The writers touch upon several points requiring a few words from ourselves, and these points we will

take up in the order in which we find them. The angle of the inner ends of the buckets in the so-called 'vortex wheel,' is given by Mr. Fairbairn, in his work on 'Mills and Millwork,' page 164, as from 30 deg. to 45 deg. (Mr. Fairbairn speaks of Professor James Thomson, the patentee of the wheel in question, as 'one of my own pupils,' in erroneously giving him credit for the invention of 'turbines in which the water flows horizontally inwards.') It is our impression that the angles mentioned were given in a paper upon this wheel once read by Professor Thomson himself. If he now adopts an angle of 25 deg. from a tangent at the extremity of the buckets, we must suppose that he is giving less of the objectionable reversed curvature to the buckets than he formerly did, or possibly he makes the circle of the inner extremities of the buckets greater than one-half of the whole diameter of the wheel. In either case, or in both, the partial return to the practice of former makers of inward-flow turbines must, we should say, have been attended with advantage.

"We are next told that 'the velocity of the outer circumference of the Fourneyron turbine, where the water leaves the ends of the vanes, may be fairly taken, for this comparison, as equal to that due to the whole fall.' We cannot answer for everything that M. Fourneyron may have done, but in no good outward-flow turbines with which we are acquainted is the velocity of the outer circumference equal to that due to the whole fall, or anything near the whole fall. In outward-flow wheels giving from 78 to 79 per cent. of the full theoretical effect due to the water, the velocity of the inner circumference has ranged from $54\frac{1}{2}$ per cent. to 67 per cent., and the velocity of the outer circumference from 68 per cent. to 83 per cent. of that due to the whole fall. In other words, the velocity of the outer circumference ranged from that due to 46 per cent. of the fall up to that due to 69 per cent. of the fall; 46 per cent. of the whole fall generating 68 per cent. of the velocity due to the whole fall, while 69 per cent. of the whole fall would generate 83 per cent. of the velocity due to the whole fall. The relative velocities of the discharging ends of the buckets are made use of, by our correspondents, to show that the inward-flow wheel *may* have a more obtuse angle, between the ends of the buckets and tangents to the circle,

than outward-flow wheels. They do not mention, however, that the inward-flow *must*, other things being the same, have a more obtuse angle for the buckets than an outward-flow, in order to properly get rid of the water,* and to prevent its being forced into a direction nearly opposite to, instead of at right angles to, that in which it entered the wheel. This would, indeed, be a flow of the water 'backwards,' as our correspondents use the term, whereas, in their wheel, the water should only flow forwards and towards the centre, and were the buckets continued to the centre (if we may for an instant suppose such a thing), the inner ends of the buckets would require to be radial to the wheel. More strictly, as the inner ends of the buckets approach the centre of the wheel, so must they, *pro tanto*, assume the direction of radii to the wheel. All this, however, has nothing to do with the fact, that whatever centrifugal force is left in the effluent water is exerted against the head acting on the inward-flow wheel, and in favour of the head acting on the outward-flow wheel. This is the main point which we have all along urged against inward-flow wheels.

"Next as to the unintelligible, or, if intelligible, incorrect statement of Professor William Thomson, as quoted by Mr. Mallet, and again by ourselves in an article on turbines in our impression of December 5th. If the statement means what our correspondents state that it does, it is untrue, because, 1st, in well constructed outward-flow wheels the velocity with which the water moves in the buckets is less than that theoretically due to one half of the fall—that is to say, less than 70·7 per cent. of the velocity due to the whole fall. A velocity of 62 of that due to the whole fall, corresponding to 38½ per cent. of the whole fall, is a common velocity for the passage of water through the narrowest parts of the buckets of good outward-flow wheels. 2nd, Whatever may be this velocity in outward-flow wheels, there is nothing whatever in the principle of construction of inward-flow wheels, as a class, which can necessarily cause the velocity of the water through the buckets to differ from that in outward-flow wheels. Professors William and James Thomson have shown a want of knowledge in contending for any such difference. In respect, therefore, of the friction of the water in

the buckets, there is no necessary difference between the outward-flow and inward-flow wheels.

"Our correspondents then quote a number of authorities to show that no turbines can give off more than 75 or 76 per cent. of the power of the water. This limit is one deduced from theory, while authorities entitled to greater confidence assign 88 per cent. as a result actually attained in practice. Our correspondents admit that Mr. J. B. Francis' statements are probably 'not far from the truth.' And, in almost the next sentence, they commit a flagrant error, in representing the highest efficiency reported by Mr. Francis as .79753, and as having been obtained from an inward-flow wheel. Mr. Francis had stated that two out of three outward-flow wheels, of 190 horse-power each, had been most carefully tested at the cotton mills of the Appleton Manufacturing Company at Lowell, that the data were put into his hands for computation, and that he found that 'the mean maximum effective power of the two turbines tested was eighty-eight per cent. of the power of the water expended.' We might employ a harsh term to designate the manner in which our correspondents have made use of Mr. Francis' work. He had, it is true, himself designed four outward-flow turbines of 165 horse-power each, and the highest result obtained from the only one of these tested was .79375, and he had also designed two inward-flow wheels of 230 horse-power each, having the great external diameter of 9 ft. 4 in. (8 ft. internal diameter) and one of these once gave .79753 efficiency. The 40 buckets of these wheels made the sharp angle of 11 deg. with a tangent to the inner circumference. These wheels were made with great accuracy, and were probably the most complete and most nearly perfect inward-flow wheels ever made, whereas Mr. Francis' outward-flow wheels, made for the Tremont and Suffolk Mills, were not fitted with the 'diffuser,' invented by Mr. Boyden, and applied by him, for the purpose of utilising the energy of motion in the water on leaving the wheel. The large turbines of the Appleton, Merrimack, and some other cotton mills at Lowell, have these diffusers, and are known to utilise from 80 to 85 per cent. of the efficiency of the water.

"All that has been said in favour of the inward-flow wheel *does not* remove the facts, 1st, that more or less centrifugal

force is carried away in the water issuing from all turbines, and 2nd, that this force acts antagonistic to the water doing its work in the inward-flow wheel, and in favour of the water doing its work in an outward-flow wheel. Upon this very point Professor J. Thomson 'staked' (and, it can hardly be denied, lost) his 'professional reputation' in our own columns last summer. A like want of knowledge has led to the absurd statement as to the velocity of the water being less in the buckets of the inward-flow than in those of the outward-flow wheel. If the velocity of the water were really less in one wheel than in the other it would only follow that less water was passed and less work done. The standard of comparison between any two turbines must of course be the quantity of water passed in a given time on a given fall, and if these be the same, and the area through the narrowest parts of the buckets be the same in both wheels, the water must have the same velocity, and its motion be attended with the same amount of friction in both turbines, whatever may be the principle on which they may be constructed. The best turbines of all classes move, with relation to the water passing through them, with a velocity equal to that theoretically due, not to one-half, but to about three-eighths of the fall, and often, indeed, with both outward and inward-flow wheels, with the velocity due to but 31 per cent. of the fall. An inward-flow wheel must, in order to pass a given quantity of water on a given fall, be of larger diameter than an outward-flow wheel, and as the guides, in the first-named wheel, are external, the weight and cost of fitting will be greater for the inward-flow wheel. The so-called 'vortex wheel' differs from other inward-flow wheels chiefly in having but four guides, and buckets of needless length, and having a reversed curvature wanting correspondence with the path of the water through the wheel, and the 'vortex,' or any other inward-flow wheel, if made for the same quantity of water, the same fall, and the same number of revolutions, and of the same materials, will be found to cost considerably more than the outward-flow wheel.

"But for general purposes we believe the parallel flow or Jonval wheel to be preferable to either the outward or inward-flow wheel. Our reasons are, chiefly, that while the action of the water is scarcely less effective than in the Fourneyron wheel, the

Jonval wheel may, with the aid of the 'draft box,' or suction pipe, be placed above the tail water; and if the fall be over 25 ft. the wheel may be placed even 25 ft. above the tail race, and thus, while obtaining the same effect as if the wheel were submerged, it may at any time be left high and dry for repairs by simply turning off the water. Thus, with a few feet of piping a Jonval wheel giving from 75 to 80 per cent. of effect may be more cheaply put up than the cheapest water motor of any other description. Our correspondent seeks to throw doubt upon the experiments made by the Philadelphia Water Department, and yet of nine trials made with one form of Jonval wheel, with the gate fully open, but with loads varying in nearly all the trials, the variation in efficiency was but from .7771 to .8210, the quantity of water used in each experiment having been actually measured, and not estimated by a formula. With another form of Jonval wheel, the trials having been made under precisely the same circumstances, the variation in twenty trials, during which the gate was fully open, was but from .7857 to .8777, the average being .8485. These differences were fully accounted for by the differences in the weights lifted; the load on the wheel, with the lowest efficiency, having been nearly 20 per cent. greater than in the trial giving .8777, or $87\frac{3}{4}$ per cent., which was exclusive of the friction of the wheel and testing apparatus. The Philadelphia experiments showed, on the whole, a remarkable degree of correspondence and probable accuracy; and we have no hesitation in saying that Jonval wheels may be constructed to give off 85 per cent. of the full theoretical effect of the water expended."

DIVISION SIXTH.

RAILWAYS.

The most novel application of railways of late to large towns has been in the introduction of underground lines. The Metropolitan Underground Railway in London has been a complete success, both in an engineering and commercial respect, so much so, that several others are proposed, and are before Parliament at

present. These, however, are likely to meet with strong opposition from the Metropolitan Board of Works, coming in contact, as they do most seriously, with their extensive drainage operations. The only remaining difficulty in underground railways, not quite solved, is the application of locomotive power without occasioning the production of noxious gases from the furnace of the boiler. At present, when the engine enters the closed tunnel the exhaust steam is turned into the tender, and there condensed, but there still issues from the mouth of the funnel much sulphurous acid and other disagreeable products. It has been proposed to work these engines by atmospheric pressure; this, no doubt, would be very good, so far as securing efficient ventilation from the exhaust vent, but the power realized from compressed air is not more than 50 per cent. of the power required to compress it, besides the objectionable heat generated by compressing air. The writer has had occasion to design some heavy air-compressing engines to compress air to 50 lbs. per sq. inch, and he found, in working the air cylinder at a rate as slow as 80 to 100 feet of piston per minute that the temperature of compressed air, although the cylinder was surrounded with water, rose very shortly to close upon 300° Fahr., and in using this air in this particular case not more than 40 per cent. of the original power was realized. Mr. Fowler, we believe, has made some experiments upon hot water locomotives, that is, water contained in a reservoir at 400° or thereabout, but as yet the matter has not been fully developed. Another and perhaps a more feasible plan is proposed by Messrs. R. and N. Hawthorn, the eminent locomotive engineers of Newcastle. A communication on this subject was made to the members of the British Association, of which the following is an abstract:—

“A system of working railways by fixed engines and ropes has long been in use on the colliery railways around Newcastle-upon-Tyne, as well as in other districts, and a plan for the same was made the subject of a patent by Mr. Benjamin Thompson, then of Ayton Cottage, in the county of Durham, and was introduced on one or two colliery railways. It consisted of a succession of fixed engines at certain intervals from one end of the line to the other, each engine being employed to work a portion of the railway in the following manner:—

"The engine gave motion to two rope rolls, and the rope from one of those rolls was attached to one end, and the rope from the other roll was attached to the other end of the train. While one of the rope rolls was disengaged from the engine, and allowed to run loose, the other was in gear, and the rope from it was passed along the line, and round a loop sheave, then brought back and attached to the train. The engine being put in motion the train was dragged to the furthest end of the section worked by that engine, at the same time unwinding the rope from the loose roll, and taking it with it to be afterwards employed to drag back the returning train. This was continued throughout the line, each successive engine taking up the train, and carrying it over a section of the line. This method was not a satisfactory one for the conveyance of passengers, as the rider or guide in charge had not sufficient control over the movements of the train, and there is an objection to the carriages being attached directly to the rope, and at such a distance from the motive power. Ropes have been, and are yet, applied in other ways, for instance, on gravitating or descending planes, down which a loaded train passes, having the rope attached to the after end, round a sheave at the top of the incline, and thence down to the ascending train, and thus the descending loaded train draws up the ascending light train; or, where the load has to ascend, a fixed engine is employed to draw it up, and the descending train takes the rope down with it. Ropes are also applied in a variety of ways to the working of inclined planes on passenger railways. Thus there is nothing new in the use of stationary engines and ropes for working railway traffic. It will be observed that, in all the cases referred to, the rope is attached directly to the carriages.

"In the proposed plan now offered to the notice of members of the association the means of communicating motion to the train gives greater security, as well as the advantage of avoiding the necessity of attaching a train to the end of a rope, thus ensuring to the guard as complete control over the movements of the train as he now has in the employment of the locomotive engine. In the new system, it may be stated without exaggeration, that the rope drives the locomotive wheels, and each carriage carries its own railway.

"It is proposed, with the ordinary construction and gauge of railway, to place in the intermediate space between a double line of rails a series of double grooved sheaves, fixed in spindles or axles which pass across under the rails, extending a little over the centre of each line; a plain wheel or roller is fixed upon each end of these axles, by which the motion is communicated to the train from a stationary engine or engines, placed at a convenient point of the line—by means of an endless wire or rope, passing alternately over and under the grooved sheaves to the extremity of a section of the line where it is taken round a large loop sheave, and returned to the engine, now passing over each sheave which it before passed under, and *vice versa*, the double groove providing for the rope crossing itself without contact.

"Having traversed twice along the line of sheaves the rope goes again on to the large winding sheave of the engine, on which a sufficient number of turns are taken to ensure the requisite friction.

"From this arrangement of the rope on the sheaves it will be seen that every alternate sheave runs in the same direction, and every intermediate sheave in the contrary direction; and this motion is communicated to the traction wheels or rollers before mentioned.

"It is proposed to construct the carriages for passenger lines on the principle of those used in America and on the Canadian railways, of a length of from 60 ft. to 75 ft., and supported on bogies, and capable of seating from 120 to 150 passengers, each carriage to be fitted with traction bars—these bars extending over two or more alternate traction rollers—and to be furnished with the ordinary flanged wheels, for running on the rails. The traction bars, of which there are two, are placed side by side, at such a distance from each other as may be necessary to meet the requirements of the line; and these traction bars are worked either in connection with, or independent of, each other by a suitable arrangement of levers or other gearing, by which either of the bars can be raised or depressed, thereby bringing a portion of the weight of the carriages upon the traction wheels or rollers, thus giving motion to the train of carriages in either direction. Or both these bars can be raised out of contact with

the traction wheels or rollers, and the train left free from all tractive force.

"The traction bars will be nearly the full length of the carriage, and the traction rollers will be placed about 18 ft. apart, or at the rate of 293 per mile.

"The carriage made in this way is adapted for running with either end first, being provided at each end with a platform, on which the driver stands to work the traction bars; and it is considered that, for ordinary traffic, one carriage will be sufficient to form a train, but two or more may be attached to each other, or the number of trains of a single carriage each may be increased to meet the requirements of the traffic.

"The motion of the train can be quickly and certainly retarded or stopped by raising one bar and depressing the other, in the manner of a brake, thereby reversing the direction of the driving motion.

"A separate or independent traction carriage may be used, fitted with the traction bars and gear; but it is considered that such an arrangement would, in most cases, only be adding a useless and unnecessary weight to the useful portion of the train.

"The present line of underground railway through London, from Paddington to Farringdon-street, is favourable to the use of the locomotive engine, where so much of the surface of the ground under which it passes is unoccupied by buildings, and readily admits of a good deal of open cutting and ventilation at the stations, which cannot be the case where the railway passes under the densely-populated parts of a city, as those projected in London must do. In such cases it will be necessary to provide for working in a continuous tunnel of, perhaps, three or four miles in length, in which the steam and smoke of locomotive engines would prove obnoxious to a much greater extent than is experienced on the present line, which is only partially an underground railway. As there does not appear to be any means of remedying these evils, except at a very extravagant cost, it is believed that the new system may be introduced with advantage in such cases as are above referred to, viz., railways passing under large towns, or in situations where opportunities do not occur of having openings to the surface.

"The maintenance of the engines will be considerably less

than with locomotives, to balance the expense of keeping in working order the sheaves, ropes, &c., which will cost more than an ordinary line.

"Both calculation and experiment on the adhesion required to propel a train remove any reasonable doubt of being able, by the new system, to obtain sufficient tractive force by the tractive bars and rollers, and it is evidently quite feasible to increase this tractive force if required.

"With a locomotive a train of fifteen or twenty carriages has to be drawn by an intense pressure on six or eight points, and it is this which adds such a heavy item to the cost of railway maintenance. This disadvantage will be, to a great extent, remedied by the proposed system, the tractive force being more disturbed, and consequently, the wear and tear diminished. Finally, if such a system as the one proposed can be introduced free from the objections that have hitherto been considered inseparable from the use of ropes, it will greatly facilitate the construction and extension of underground railways without their present draw-backs."

The carriages of the underground railway are beautifully illuminated with gas supplied from receivers over-head, containing gas at a very high pressure. On this subject a correspondent of the '*Practical Mechanics' Journal*' makes the following suggestions as to the various points to be observed in lighting trains with gas:—

"The pioneers in this country, in the construction of apparatus for compressing gas, and using it in a portable form, were, Thelluson, Gordon, and Heard; and more recently in France, a system has been adopted of supplying rich portable gas, which has extended itself to several important towns on the Continent, and with a very fair amount of success. There are companies established at Paris, Milan, Turin, and Moscow, their object being chiefly to supply gas to those parts not within the range of the ordinary gas companies' mains, so that they do not act antagonistically to them. M. Hugon, of Paris, is more or less at the head of each of them, he being the gentleman whose mode of production, compression, and regulation of the gas, has been adopted. In America, the steamboats and some of the railway trains are lighted with gas made on the boat or train, as

well also as by the means which have so frequently been tried in this country.

"Thompson and one or two others have been tolerably successful in the lighting of railway trains, but it may be presumed that their systems have many objections, or railway companies would assuredly adopt some such plans of lighting their carriages, which for many self-evident reasons are preferable to oil. At the Society of Arts, Mr. Teulon, representing the railway interest, clearly showed that while he was thoroughly acquainted with what had already been done, yet that the result, so far, was anything but satisfactory, at least not so much so as to warrant the companies adopting it generally.

"I am aware that the gas, as delivered at the houses of customers at Paris, which is stored in reservoirs at five atmospheres pressure, is readily regulated from that pressure down to that which is necessary for being properly burnt—say equal to a column of water five or six-tenths of an inch in height, but the means by which that is accomplished there, cannot be made available for lighting railway trains with gas.

"I venture to say that there are considerable difficulties to overcome before a proper system of lighting railway carriages, as we now find them, and for long distances, can be successfully brought into use.

"The conditions which railway companies must have are:—

"1. That but little room be taken up by the apparatus.

"2. That the application be readily made to existing carriages at little cost.

"3. That the light be better, and at less cost, taking everything into consideration, than lighting by oil.

"4. That the apparatus be simple, and that each carriage be lighted independently of the others, so that they may be detached at pleasure, without putting the light out.

"5. That the light last as long as the oil lamps, or say from London to York, Holyhead, Exeter, or Dover.

"6. That it be as certain in its action, under all circumstances, and that defects be as readily corrected as by the present mode of lighting.

"The plan adopted at the Metropolitan is not generally applicable, and only for such an exceptional line of railway as it is;

for, to use gas at the mere pressure of that which is necessary for burning it, would require for the journey between London and York, half as much cubical capacity as the carriages themselves.

"In order to fulfil the conditions I have named, the gas must be condensed to ten or fifteen atmospheres, and the difficulty is to reduce that pressure down to five-tenths of an inch column of water, and to maintain it at such under all circumstances, so as to comply with the conditions I have stated, and the regulator must be entirely metallic. I am fully acquainted with all the published methods from the first introduction of gas-lighting, but not any of them comply fully with what railway companies must and will have, before they generally adopt the principle of lighting railway trains with gas."

In India a most stupendous railway undertaking has been lately brought successfully to a close. In it there occurs an incline of unusual length and steepness; its length being over 15 miles long and averaging 1 in 48. An excellent description of this incline called the "Bhore Ghaut" was given in a paper read at the Mechanics' Institution, Bombay, by the President, James J. Berkley, Esq., M. I. C. E., F. G. S., Chief resident Engineer of the Great Indian Peninsular Railway. The following is an abstract:—

"What the circulation of the blood is to the individual, a complete and speedy communication is to the body politic; disease and death result from a stagnation of the current of life, while general poverty and local famine are continually present in a country unprovided with easy locomotion between its outlying districts. Good communication equalizes the prices of the necessaries and luxuries of life by adjusting and concentrating the markets; it brings the right product to the right place for its consumption, and it assimilates all the classes of a nation through facilitated intercourse and a general diffusion of comforts and luxuries. In time of war, the advantages of good roads are increased tenfold, multiplying by speed the momentum of the body of men chosen to repel an invader. The Romans—conquerors by profession and heritage—always consolidated their freshly acquired territories by sound and durable roads, many of which are still extant as ineffaceable monuments to Roman foresight and power. England—Rome's heir in many things—

has always been noted for good communications; and long before Englishmen ran the first locomotive on a line of rails, they had employed for years postal arrangements on macadamized roads peculiar to the country and unsurpassed for speed and efficiency. It is strange that the same nation should have so long procrastinated with the introduction of improved means of transit into their immense territorial possessions in Hindostan; that the palanquin, with its dusky human bearers pursuing their toilsome march under a burning sun, should only have been replaced within the last few years by carriages impelled by steam along iron roads; that the bunch of iron rings used by the native running courier to scare away the hyænas of the jungle, should have been but so lately superseded by the shrill shriek of the locomotive steam whistle.

"In a recent work it is stated that the cost of locomotion in India is such that, during the campaign in the Punjab, every man in the British army had cost £150 in transport alone; the usual allowance on an Indian line of march being one camel to five fighting men. Although the importance of easy means of transport of troops from one point of India to another was long acknowledged, and although it was generally known that India—with cheap means of transport could 'clothe the world in cheap cotton,' it has required the united stimuli of a wide-spread military mutiny on the one hand, and of a complete stoppage of our ordinary supply of cotton on the other, to overcome the obstacles in the way of a good inland communication for our East Indian possessions. At last, however, the first meshes of the iron net destined to cover the land of the burning sun are at last being laid down; and English science is now affording some compensation to a people subjugated by English lust of conquest and dominion.

"A line of mountains called the Western Ghauts run almost the entire length of the western coast of the Peninsula of Hindostan. They extend in a nearly parallel line—about 30 miles distant from the coast—the whole extent of territory between Travancore and Bombay. This abrupt and lofty volcanic scarp has offered for countless ages a serious obstruction to the communication between the western ports and the interior of the country. Until lately it took a journey of two days for travellers,

and three for goods, to traverse about 48 miles of the rude roads of the country. Along a range of 220 miles there were no hopes at all for wheeled traffic; but simply a number of precipitous foot-paths and steep rugged tracks for beasts of burden. The construction of the railway passages of the Thull and Bhore Ghauts were thus imperatively necessary before India, and especially the port and Presidency of Bombay, could enjoy the full benefit of railway communication; and the engineers of the Great Indian Peninsular Railway may well congratulate themselves on their success in overcoming the enormous difficulties of this particular portion of their line.

"The investigations of Mr. Berkley, the chief engineer, and his colleagues, on their arrival at Bombay, in 1850, resulted in the rejection of the Malsej Ghaut Railway ascent selected by the late Mr. John Chapman, and laid out and surveyed by Messrs. Clarke and Conybeare. The present Incline is a modification of a second projected design laid out in 1852, but embodying the objectionable feature of a stationary engine plane; fortunately, this has been avoided by laying out a continuous locomotive gradient from the base to the summit of the incline. After some delay, in 1853, from the hesitation of Lord Dalhousie, caused by the gigantic character of the present designs; and after some modifications during the progress of the works—scarcely to be made clear without the aid of a map—the present Incline was finished last year.

"The Bhore Ghaut Incline of the Great Indian Peninsular Railway is 15 miles 68 chains long; the level of its base being 196 ft. above the sea, and its summit 2,027 ft.; the total elevation surmounted by the Incline in one long lift is 1,831 ft., and its average gradient is thus 1 in 48. This extraordinary portion of the railway system of Western India is now successfully completed, after being in progress for seven years and a quarter; and on the 30th of last March an experimental train was run for the first time, accomplishing the $13\frac{1}{2}$ miles from Padusherre to Khandalla in 52 minutes.

"There are only two other mountain ascents in the world that can be somewhat compared in magnitude and difficulty with the Bhore Ghaut Incline. The Giovi ascent of the Apennines, and of the *Semmering* ascent of the Noric Alps, can scarcely be said

to equal in difficulty this part of the Great Indian Peninsular Railway.* The almost inaccessible volcanic scarps of the Bhore Ghaut had to be encountered by cuttings of a most difficult character; in some situations, one-half of the line is on rock benching, while the other half had to be carried on a lofty embankment, or on an embankment supported by a wall of masonry. In other places, it was impossible to use battering walls, and the line had to be carried on arches; while in some instances, one-half of the width of the line stands upon rock benching, and the other half upon vaulted arches; in fact, the great number of extraordinary cross sections—nearly 2,000—is probably unparalleled by any other engineering work. In the vicinity of the numerous beds of basalt, of intense hardness, intersected by the incline, great difficulty was caused by some of the masses of rock falling away in large blocks as the cutting proceeded. One portion of the line shows a vertical face of 60 ft. to 70 ft. for about a quarter of a mile. All the materials had to be hauled up a great length of new roads, whose formation was necessitated by

* The following is a table compiled by Mr. Berkley, and giving a comparison between these two Inclines and that of the Bhore Ghaut:—

Name of Incline.	Length.	Total Ascent.	Average Gradient.	Maximum Gradient.	Sharpest Curves.	Total Length of Tunneling.
	Miles.	Feet.				Miles.
GIOVI INCLINE.....	6	889	1 in 36	1 in 29	20 chains radius.	2.55
SEMMERING INCLINE.....						
Ascent from Peyerbach to the Semmering.....	13½	1325	1 in 47	1 in 40	{ 30 curves of 18 chains radius and 38 curves of 14 chains rad. }	2.66
Descent from the Semmering to Muerzschalg.....	8½	705	1 in 50	1 in 50		
THEORE GHAUT INCLINE ...	15½	1831	1 in 48	1 in 37	{ One of 15 and two of 20 chains radius. }	2.26

distant Giovi Incline commences 7¾ miles from Genoa, at a point 295 ft. Travanco level of the Mediterranean, and ascends the Apennines. The has offered Incline is replete with extensive and extraordinary works, and munication ry operations and study occupied from 1842 to 1848, a period country. Un it was opened in May, 1854, its construction having taken

the steep and mountainous character of the Ghauts; ten miles of cart-road, more than twice that length of bridle and bullock-path, and a railway siding of nearly two miles, had to be laid down in order to bring up the materials. The two miles and a half of tunnelling have been cut into trap rock of great hardness, and the precipitous character of the hills rendered it impossible to sink shafts. The tunnels had to be entirely mined from both ends; and the sharp curves and steep gradients made this a work of some nicety; while the enforced absence of shafts rendered the ventilation of the headings exceedingly difficult. The arches of the three quarters of a mile of viaducts are built of squared stone laid in courses, with ashlar and quoins. No bricks were used in any of the works. Their foundations were required to be excavated to a great depth before a sufficiently secure bed of rock could be reached. Up to the surface of the ground the viaducts were built of solid block-in-course masonry, and above that of block-in-course face-work, tied firmly through, by bonds of block-in-course, to the inside work of sound rubble.

"The engineering difficulties we have slightly alluded to—hard to surmount in any country—were doubly so under the burning sun; the miasmatic exhalations of the soil; the formidable Ghaut monsoon; the drought of water; all specially characteristic to that part of India. The railway works had to be almost completely stopped during the four months each year of the rainy season. In March, 1861, 42,000 men were employed on the works; in the following June, this number had dwindled down to 4,000. The disadvantage of the annual dispersal of the skilled work-people was, however, in some degree overcome by employing them in the Poona quarries in preparing the stones. The scarcity of water during the hot weather was another great difficulty; and the water for drinking purposes, and for the masonry, had to be brought up from the Oolassa River—a distance of 4 to 5 miles from the centre and some of the lower part of the incline—on bullocks. 1,500 of these animals were constantly employed in the carriage of water when the works were in full progress. In the season of 1859-60, the cholera caused a great mortality, and an almost complete dispersion of the work-people. The inferior labour of the natives, as compared with that of Europeans, also deserves to be regarded when instituting

a comparison between the Bhore Ghaut Incline and the two similar works carried out in Europe.

"One of the most original features of this steep railway incline consists in the peculiar system of 'reversing stations,' adapted to accomplish an increase of the length of the base, and a flattening of the gradients; as also some reduction of the very heavy works that would be otherwise required. It is an application of the American 'zigzag' plan of laying out a mountain railway ascent. The line is forked into something like the shape of the letter Y; and the engines being turned at the station, the tail of each train becomes the head. It appears to go back as it leaves the station; but the train continues its journey by running up the other branch of the fork. This plan permitted an alteration in the direction of the line at a very acute angle, by means of points and crossings—avoiding the otherwise necessary adoption of curves of an objectionably small radius.

"The rails of the permanent way were manufactured to a special specification, prepared by the then consulting engineer—the late George Stephenson. They weigh 85 lbs. per yard, and four-fifths of the number are 21 ft. long, in order to lessen the amount of joints. The entire piles out of which the rails were rolled, were built up with hammered iron. In order to protect them from the heat and moisture of the long sea voyage to India, all the rails were dipped while hot into hot linseed oil—a process which has been very successful in also preserving the rails under wear. The joints are fished, and they rest on small cast-iron saddles, spiked to longitudinal timber bearers, the ends of which are secured to the transverse sleepers by means of fang bolts. All the chairs were cast from iron subjected to a daily test by the inspectors of the company—the rail-bearing surface being chilled.

"The engine rolling stock for working this incline consists of seven pairs of double four-wheeled tank engines coupled back to back, or rather fire-box to fire-box, and running in pairs. This arrangement, while affording the requisite tractive power for steep inclines, adapts itself very easily to sharp curves, and in our opinion is infinitely superior to the monstrous Engerth engine, so affectioned on the Continent. Similar engines are par-

tially used on the Giovi Incline of the Turin and Genoa Railway, and they were also proposed by Stephenson for the Semmering Incline of the Vienna and Trieste line."

On railway curves and their evil effects on the rolling stock, Mr. William Bridges Adams has addressed the following letter to the '*Practical Mechanics' Journal*:'

"On railway curves it is a practice to elevate the outer rail above the inner one, with a view to balance the centrifugal force by gravitation,—a practice that obtained on the highway curves in the old coaching days of high speeds, and which still obtains in the sharp curves of the amphitheatre, where both horse and rider lean over towards the centre of an angle corresponding to the speed.

"But in the old coaching days the wheels on either side were enabled to vary their speed to suit the length of the curves they described, and the inner wheels made fewer revolutions than the outer. So, also, it will be found in the amphitheatre that the inner legs of the horse makes shorter strides than the outer. Otherwise the animal would be driven against the barrier—his leaning inwards notwithstanding.

"On a railway wheels proper, *i. e.*, revolving independently of each other on the same axle, are not used, but there is a contrivance intended to produce a compensation. The periphery of each wheel is coned, or has a varying diameter, largest internally and smallest externally. Theory says that the centrifugal force tends to drive the wheels against the outer rail, and so bring the larger diameters into action thereon, and the smaller diameters into action on the inner rail, thus producing compensation and curvilinear movement.

"But theories are not sound when they do not take into account all the data which may affect them. If the play or width between the rails, *i. e.*, the gauges, be not wide enough for end-long movement of the axle, this conic compensation is defeated. And, if the axle be so fixed in a long carriage or engine that, while going round a curve, it cannot point to the centre of that curve, the compensation will be imperfect. The actual condition on almost every curved line, whether the proposed curves of the engineer or the multiplicity of short and sudden curvatures and variations of rail surface induced by wear or imperfect workman-

ship, the actual condition involves both the defects—wrong position of the axle and wrong diameter of the wheel.

“The result is that the wheels become, not rollers, but sledges, and induce that grinding vibration which physicians object to for their nervous patients, and the existence of which is ignored frequently by those said to be experts.

“The proof—Centrifugal force and inward gravitation are nicely calculated and balanced by engineers to determine the exact elevation of the outer rail above the inner due to each curve. Theoretically, the weight of the engine leaning inwards should tend to grind the inner rail, but the exact opposite is the constant fact. The inner edge of the outer rail is ground away and polished, even when on a curve of 600 ft. radius the outer rail is elevated 6 in.—equal to an incline of one in nine.

“The mechanical reason for this is that the inner wheels running in diameters too large for the path of the inner rail, are acting with an outward thrust that wholly overpowers the gravitation inwards, that very gravitation tending to increase the bite or adhesion of the inner wheels, and to force the lighter loaded outer wheels to ‘skid’ and slip against the outer rail with a force tending to burst the fastenings by the flange action. If, under these circumstances, there be a yielding or sinking of the inner rail, the adhesion of the inner leading wheel will be lessened, and the flange force of the outer wheel will be increased, tending to throw the engine off internally. If, on the contrary, there be a yielding or sinking of the outer rail, the flange force will be weakened, and the adhesive force of the inner wheel will tend to throw the engine off externally.

“Other things being equal, the greater the length of the wheel base compared with its breadth the steadier the engine will run on straight lines, but the greater will be the risk of its getting off the rails on curves unless provision be made to keep the axles true to the curve centres, and to adjust the diameters of the wheels to the respective lengths of the rails.

“Such provision is not made—is scarcely thought of being made—and as a general rule would be thought a heresy, would be objected to, and yet herein lies the whole of that “mystery” so frequently adverted to as the solution not to be compre-

hended, when railway accidents occur by engines getting off the line.

"All railway practice is full of the proof. Why do rails glisten? Why do the treads of wheels work into deep hollows? Why are wheel flanges cut to the sharpness of knifeblades? All this is proof positive of sliding friction, and not of rolling.

"And now to the proof negative. A resident railway engineer applied to four engines running on a line of sharp curves and steep gradients four classes of tyres of different qualities, varying in price from £75 per ton to £25 per ton, representing thereby their various degrees of durability. To three of the engines the wheels were applied on the usual mode with the best tyres. To the other engine, working under far more unfavourable circumstances, the lowest class tyres were applied, so that the wheels obtained compensation in curves. The result was that the inferior tyres exhibited about two and a half times the durability of the best. And, as action and reaction between tyre and wheel must be equal, the saving on the rails must have been proportionate to the saving in tyres, *i.e.*, the seven years' duration grew into seventeen so far as that engine was concerned.

"So much for the pecuniary advantage in wear. Yet this pecuniary advantage represented also a corresponding element of safety. Possibly, this practical fact, still only a portion of what is needed, may in process of time and by the help of accidents grow up into recognition, and, like the grain of mustard seed in the parable, become multiplied till that source of railway accidents disappears."

DIVISION SEVENTH.

IRON.

The subject embraced in this division is of paramount importance to the engineer, and of the most comprehensive character, embracing, as it does, so many details of scientific and practical importance. It would be idle to expatiate in this work upon the many and various applications of this most valuable of

metals; suffice it to say, that to become thoroughly acquainted with its various conditions and qualities is the first step towards the successful application of it to the various works met with in engineering practice. The various sources of iron, as is well known, is from the different ores which contain a large proportion of pure iron in combination with carbon, sulphur, phosphorus, and other bases. The most common ores are as follows:—*Magnetic oxide of iron*, which consists of 3 atoms of iron in combination with 4 of oxygen (Fe_3O_4) and containing about 73 per cent. iron. *Red Hæmatite*, or peroxide of iron, contains 2 atoms of iron in combination with 3 of oxygen, (Fe_2O_3), and containing 70 per cent. iron. *Brown Hæmatite*, a hydrated peroxide of iron, is composed of 2 atoms of peroxide of iron, 3 atoms of water, and containing 60 per cent. iron. *Black-band Ironstone*, a carbonate of iron, is composed of 1 atom of protoxide of iron in combination with 1 atom of carbonic acid ($\text{Fe. O} + \text{CO}^2$), and contains 48 to 50 per cent. iron. Iron is also found in combination with sulphur, called iron pyrites, but this is unimportant, such an ore being useless to the iron master, owing to the pernicious effects of sulphur in iron, whether existing in the fuel or the ore itself.

The process of extracting iron from its ores may be briefly stated as follows:—If the ore to be operated upon is a carbonate, it is reduced by means of heat, which drives off the carbonic acid, while a quantity of lime is used to remove the earthy constituents with which it combines, forming a glassy refuse, known as “slag.” The iron thus remaining in the furnace is principally oxide, but has its oxygen removed by the large quantity of carbon with which it is in contact, and the final product is a carburet of iron, known as cast iron, it being a mixture of pure carbon and iron. Other impurities, however, frequently require removal, such as sulphur and phosphorus; this is effected by the action of chlorine, which is introduced into the furnace in the form of chloride of sodium (Na. Cl.) or common salt.

The iron of commerce, as is well known, exists in three different forms, *malleable* or *wrought iron*, *cast iron*, and *steel*. Malleable iron is the metal in its nearly pure state,—steel having a certain proportion of carbon in combination, while cast iron has still more.

The processes by which these various conditions of iron are

obtained are very numerous. The great bulk of iron obtained is first reduced to the state of cast iron, then the carbon is extracted by means of "puddling," or exposing it to the oxygen of the atmosphere in reverberatory furnaces in a melted state. The oxygen combines with one atom of carbon to form carbonic oxide (CO), which burning with a blue coloured flame combines with another atom of oxygen, and escaping as carbonic acid (CO_2). The iron by this process loses its carbon, becomes agglutinated, and is taken out and "shingled," after which it is worked up with the steam hammer. Steel is produced from wrought iron by introducing into it the necessary amount of carbon, and this is effected, according to one process, by introducing into a retort bars of wrought iron along with carbon, the whole being maintained at a red heat for a considerable time. This is the most common process of making steel from wrought iron; but lately, both wrought iron and steel have been obtained by a peculiar process direct from the ore.

Having thus endeavoured briefly to explain the processes of obtaining the different conditions of iron, we shall return to the consideration of "pig" or "cast iron," and in doing so, the first step is to ascertain, as far as possible, the exact component parts of the different samples of cast iron, and what constitutes hardness and softness, &c., in iron.

As this is a subject the chemistry of which is still to a great extent unknown, we shall simply give the experience of practical men in connection with observed facts.

The latest solution of the question as to the state of carbon in cast iron is given by William Crossby, F.C.S., which we extract from the '*Chemical News*:'—

"I have long been of opinion that anything throwing light upon the chemical constitution of cast or wrought iron and steel is of great importance, and I submit the following considerations, which are partially supported by experiment, as tending in this direction.

"In analysis of cast iron the carbon is generally shown in two states—viz., combined and uncombined; combined as a fusible carbide, uncombined as graphite disseminated throughout the mass of the iron; and, according as the graphite or the carbide predominates, we have grey or white iron. The white is said

to owe its peculiar properties to containing but little graphite and much carbide. The grey, on the contrary, contains but little carbide and much graphite, or free carbon.

"I don't know why these views should be held, never having seen any reason given. They are the views, however, generally held, as may be easily shown.

"In the '*Chemical News*' for Saturday, January 31, 1863, in a paper on the Chemical Constitution of iron, &c., by General Sobrero, of Turin, the following passage will be found:—

"'. . . The cast iron is agitated until the moment it solidifies; for this reason, carbon cannot crystallise separately, but remains in combination, hence white iron results.'

"F. A. Able, Esq., in a lecture at the Royal Institution, April, 27, 1860, says:—

"'In looking at these specimens of cast iron, you will be at no loss to discover a very considerable difference in the appearance of most of them—indifference which is borne out by fully as great a variation in their physical properties and chemical composition. Here is a very dark specimen with glistening fracture, containing a considerable portion of carbon in a peculiar condition—in the graphitic form, as it is called.'

"Miller, in his '*Inorganic Chemistry*,' p. 879, says:—

"'In many varieties of cast iron the carbon exists in two distinct forms—one portion being chemically combined with the metal, the other mechanically diffused through it as graphite—the scales of which may be distinctly seen with a magnifying lens when the surface of a newly fractured bar is examined; these scales remain unacted upon when the metal is dissolved in dilute acid.'

"I have frequently had occasion to examine samples of grey iron with a lens, and never yet have I seen the scales here referred to; and I believe if grey iron be carefully examined, it will be found to be made up, not of iron and graphite, but of crystals aggregated together, and containing carbon and iron chemically combined. When iron is acted upon by dilute acids, as shown by Calvert, the carbonaceous matter left possesses the same form, and occupies the same bulk, and, in fact, has the same appearance in every respect as the iron from which it has been obtained.

"But, for the sake of argument, we will suppose that in grey iron the carbon is really as graphite; and here at once a difficulty meets us. How is it that grey iron is more fluid than white iron? In grey iron we have almost a pure iron (which is very difficult to make fluid at all) merely mixed with carbon. In white iron, on the contrary, the carbon is chemically combined, and we all know how much more fluid melted carbide of iron is than iron free from carbon. How is it, too, that the graphite does not separate when the iron is in the fluid state? The graphite itself is infusible, and its specific gravity much lower than the iron in which it floats, one would think that it would separate from the iron and rise to the surface. There are those who answer these questions by saying that iron is capable of dissolving graphite when it melts, and again liberating this graphite when it cools, while others say that a carbide of iron is formed when the iron melts; this carbide is again decomposed on cooling.

"I think I can prove that neither of these explanations can be correct, or, indeed, any other where it is assumed that the carbon exists in the two states, combined and uncombined. First, let us see how far the theory that the graphite, when the iron melts, is converted into a fluid carbide, holds good. Before doing this, however, let me draw attention to the fact, that iron made from the same stone, and under nearly the same circumstances, whether white or grey, contains about the same total percentage of carbon. For instance, the carbon determined by combustion, in three samples of grey and three of white iron gave the following results:—

	Grey.	Average.	White.	Average.
Carbon	3.94	3.91 per cent.	= 3.86	= 3.87 per cent. "
"	3.92		= 3.85	
"	3.88		= 3.95	
Difference			.04 per cent.	

"We will assume, now, that these irons are melted. The white is already a carbide; the grey is converted into one by melting. Here we have, then, two irons in the fluid state both containing the same quantity of carbon, yet one more fluid than the other. Let them cool and solidify. How is it that one separates graphite and the other does not? Not only this, but

we actually know beforehand which of the two will liberate the graphite, or, in other words, be the greyest. If this theory be correct, surely graphite ought not to be separated in the one case and not in the other.

"2. The theory of solution. This, I think, is even more untenable than the one already referred to. Faraday has shown that iron is capable of combining with 6 per cent. of carbon. Very few commercial irons contain more than 4 per cent., and, if a portion of this be uncombined, I cannot understand the iron dissolving without at the same time combining with it, much in the same way, that a solution of chloride of iron, and containing an excess of iron, will dissolve more iron by uniting with this iron to form more chloride.

"There is an experiment mentioned by Carey, I believe repeated by Wylde, and confirmed by myself, where a little sulphide of iron is added to melted grey cast-iron; the iron immediately changed to white, with the liberation of graphite, which rises at once to the surface of the iron; and I hold that if this graphite had been merely mechanically mixed, and yet unable to separate, separation would not have occurred on the addition of sulphide, for the quantity requisite is not sufficient to produce any material change in the physical properties of the iron while in a fluid state.

"We will now look at these questions, assuming, first, that there are two carbides of iron, and that cast-iron is a mixture of the two, with an excess, perhaps, of metallic iron, or of iron alloyed with silicium, calcium, manganese, &c. The one carbide is grey and soft, the other white and hard, and for reasons explained hereafter we must suppose the grey to be a higher carbide than the white. We can now easily account for the non-separation of the graphite when grey iron is melted, the grey appearance being due, not to this substance, but to a fusible compound of carbon and iron. But it may be said that graphite does separate when the grey iron is melted. Admitted: but how small a percentage of the total carbon present separates in this manner; and this quantity can be accounted for as resulting from the decomposition of the grey carbide; in fact, this brings us to one of the principal properties of grey iron, viz, its instability. Like some of the complex compounds known in organic chemistry, very

slight changes are sufficient to effect its decomposition. This is shown by the liberation of carbon when a little sulphide of iron is added to it while in the melted state, also by its non-production excepting when the furnace is in the very best working condition; very sudden changes of temperature, too, may effect its decomposition. In many of their properties the grey and white carbides of iron may be compared with the two compounds of carbon and hydrogen C^2H^4 and C^4H^4 . How much more stable is the lower carbide than the other; and how readily is the latter decomposed with liberation of carbon, and formation of the less highly carbonised compound.

"For the purpose of testing some of these views by experiment, I broke four pieces from a pig of very grey iron, and putting three of these in separate plumbago crucibles, each crucible was covered and coated with fire-clay, and then put into a wind furnace, which was gradually urged to a white heat. The fire was then allowed to burn out, and one of the crucibles removed, which was labelled No. 1. The fire was again lighted and urged, and again allowed to cool, and another crucible was then removed, and labelled No. 2. The third was again treated in a similar manner, and then labelled No. 3.

"My object in melting in carbon crucibles was to prevent access of air to the melted iron; if any air did succeed in passing through the crucible it would be deoxidised by the carbon of the crucibles.

"The button of iron found in No. 1 crucible was coated on the outside with 'keech,' or kish, as the graphite is generally called. When the button was split, the fracture showed it to be 'No.' 3 iron.

"The button of iron from No. 2 crucible had less graphite on the outside, and, judging from the fracture, it might be called 'No.' 4 iron.

"The button from No. 3 crucible was 'mottled,' or 'No.' 5 iron; it was quite free from graphite on the outside.

"Thus, by melting No. 1 once, 'No.' 3 iron was formed; melting a second time, 'No.' 4 iron; and a third time, 'No.' 5 iron.

"I explained these changes by supposing that in the first melting a small quantity of the grey iron had been decomposed

and a little graphite liberated; in the second melting more graphite separated, but the graphite liberated from the first melting had again united to form the white carbide; in the third melting all the graphite which had previously separated again combined, and 'mottled' iron resulted.

"I afterwards determined the carbon in the buttons of iron, and the results obtained appear to confirm the above views.

"They were as follows:—

Iron before melting, carbon	.	.	.	.	= 3.93 per cent.
1st melting	.	.	.	.	= 3.86 „
2nd „	.	.	.	.	= 3.90 „
3rd „	.	.	.	.	= 3.95 „

"The low results obtained in No. 1 is accounted for by the graphite liberated in melting. In No. 3, the graphite had again contained, hence this discrepancy is not seen.

"Another fact, which seems to support the view that the carbon in grey iron is chemically combined is the loss of carbon in the form of volatile carbides of hydrogen; when iron is acted upon by acids, no matter how grey the iron may be, or how large the crystals, there is always some loss in this manner, besides a liquid oily substance formed, which floats on the surface of the acid.

"In conclusion, many writers mention the fact, although I have never tried the experiment myself, that by exposing a bar of wrought-iron to a high temperature in a current of coal gas, it is possible to convert it into grey iron. Now, if grey iron contains large flakes of graphite disseminated throughout its mass, I would ask how these flakes can possibly enter the pores of the bar and get into its interior in an experiment of this kind? I can understand the outer coating of iron acting as a carrier of combined carbon in the inner portion, and by this means the bar of iron increasing in size and assuming a crystalline form; but I cannot understand a flake of graphite being first formed on the outside, and then forcing its way into the interior, changing the properties and form of the bar."

The quality of iron, besides being affected by the proportion of carbon contained in it, is also materially affected by the influence of the blast in the process of reduction. Vast improvement has been effected in the iron manufacture by the use of the hot

blast, although in some irons it is said that such has a deteriorating influence. As it is, the saving of fuel is immense; and some fuels are now used which, with the cold blast, would have been absolutely worthless.

In connection with this subject we quote the following from the '*Mechanics' Magazine*:'—

"When we consider the immense interests involved in the iron manufacture, it seems strange that the precise influence of the different applications of the blast on the quality of the iron produced in the blast furnace has not been investigated with the care demanded by the importance of the subject. The most eminent men of science are at variance when attempting to explain the principal phenomena resulting from the action of the tuyeres at the hearth.

"If we remember that a weight of nearly 14 tons of air is consumed in an hour in some of the large furnaces—an amount nearly three times as great as that of the solid materials; the ore, flux, and fuel—it must be evident that the volume, the density, the hygroscopic state, the chemical constituents, and lastly, the temperature of the air employed, must exercise a powerful influence for good or for evil upon the products of the furnace. The action of the air will evidently not merely confine itself to the 'yield' or quantity, but will also exercise an influence on the 'make' or quality, of the pig.

"The density of the blast employed has a considerable influence on the smelting operations, and it is principally determined by the dimensions of the furnace and the kind of fuel employed. The season of the year also requires some variation in the pressure of the air; and when its density is diminished by the heat of summer, the blowing engine has to make up the deficiency by increased speed, in order that the furnace be supplied with the requisite amount of oxygen. Before the introduction of blowing engines worked by steam, great difficulties were encountered in the use of coke and coal in the furnace. About 2 lb. to the square inch is the minimum pressure of air now employed, and this density is generally increased with the density of the fuel until in some cases it reaches $3\frac{1}{2}$ lb. to the square inch. Considerable difference of opinion still exists as to the precise shape of the tuyeres and the exact number to be employed. Mr. Tru-

ran patented in 1855 (No. 1730), 'a mode of constructing nozzle pipes so that they should deliver through one tuyere two or more jets of blast, hot or cold, of like or different densities. The nozzle pipes may be divided by partitions or be double, one being within the other, so that the outer one delivers an annular jet, and the two jets may be supplied from different pipes, and be of different densities or temperatures.' We do not know whether this plan has ever been tried. The blast is generally applied by means of three tuyeres, but as many as ten or twelve nozzles are sometimes used. The small tuyere system is especially adopted in Scotland. It is to be regretted that exact data do not exist as to the relative values of the two systems.

"The hygroscopic state of the air, or the amount of moisture contained in the atmosphere, is another potent element of success or failure. It is estimated by Mr. Truran, that about 25 tons of air are consumed per ton of metal, say dark grey pig iron, and thus, with a make of 120 tons per week, the amount of blast consumed would be 3,000 tons. According to Dalton, the air in England contains about 1.42 per cent. of moisture in dry weather, and more than double that amount in wet weather, so that we have a quantity of from nearly 50 to 100 tons of water discharged weekly into the furnace. This is, no doubt, the explanation that there is less fuel consumed and a better quality of metal produced in winter than in summer. The increase of make is, in fact, estimated to be from 4 to 5 per cent. greater during the winter months. The chemical constituents of atmospheric air being invariably the same, it could only be by artificial means that any action on the furnace could be sought for by changing the chemical composition of the blast. Various attempts in this direction will be found recorded in Her Majesty's Patent Office. Thus we find one invention (Patent No. 6,948, Old Law), proposing to inject 'pure hydrogen gas' into the blast furnace. Apart from the risk of explosion, the great expense in procuring the gas would of itself form an insuperable bar to the practical introduction of this process.

"The precise effect of raising the temperature of the injected air to about 610 deg., or the use of the *hot* blast, is still a debatable point with those concerned in iron-making. The question may be divided into three separate heads; the first

being the influence of the hot blast on the economy of fuel, the second its action on the quality of the iron produced, the third being the commercial or trade value of the hot blast.

"There is no doubt that the consumption of furnace coal is reduced by the hot blast. The saving effected varies greatly with different kinds of coal and ore. Taking the coal used in the stoves for heating the blast into account, the saving effected has been estimated at 3 cwts. of coal per ton of pig iron in Wales, and from 6 to 7 cwts. in Scotland. Various reasons have been given to account for this economy of fuel. By some it has been ascribed to an annulling of the cooling effects of the cold blast on the combustion of the furnace; by others, that a hot blast supports combustion better than a cold blast; the relative proportions of the oxygen and hydrogen on the air, are, however, unaltered by the addition of heat. Mr. Truran ascribes the economy effected by the hot blast to a reduction in the quantity of coal required in the furnace from the extraneous heat thrown in by the blast, as a reduced proportion of coal to ore is always succeeded by an increased quantity of iron produced. The amount of coal required in the furnace being thus lessened, there is a less volume of blast required, the additional result being a diminished consumption of fuel in the upper parts of the furnace. Briefly stated, the economy of fuel effected may be ascribed to two causes; the reducing power of the heated blast injected at the bottom of the furnace, and the lesser proportion of carbons in the furnace to the volume of the blast.

"With regard to the influence of the hot blast on the quality of the pig, we are still somewhat in the dark. There is no doubt, however, that the use of such a powerful means of acting on the furnace may, in unskilful hands, lead to bad results. Mr. Robert Mallet, in his work 'On the Physical Conditions Involved in the Construction of Artillery,' ascribed the 'much discussed and unquestionable (?) inferiority of hot blast iron over cold' to unnecessary heat of fusion, caused by an unskilful use of the hot blast. 'Unnecessary heat of fusion injures the quality of the metal, as unnecessary heat of "pouring" injures the quality of the casting. It does this in two ways—by the introduction of foreign earthy and alkaline bases, which greatly reduce the cohesion, and far more by the great increase of surface, produced

by extreme elevation of temperature, in the disseminated plates of graphite. These, scattered through the mass, like mica or hornblende in granite, present at their innumerable planes of cleavage almost no cohesion; but these planes are, in accordance with the general law of arrangement, in planes of least pressure, found mainly to coincide in parallelism with those of the crystals of the iron itself (*i. e.*, the carburet of iron, which constitutes the metal of cast-iron chiefly), so that the total deterioration of strength is very great; and this is, in fact, the secret of the much discussed and unquestionable inferiority of hot-blast iron over cold; nothing more than the elevated temperature introduced in the blast furnace.' Fully admitting that the injudicious use of the hot blast may produce the injurious effects ascribed to it by Mr. Mallet, we nevertheless differ from him in his sweeping condemnation of the process. To corroborate our opinion, we will further quote the following:—Mr. Hodgkinson, in his report on the experiments on hot and cold blast iron, made by Mr. Hodgkinson and Mr. Fairbairn for the British Association, says: 'It is rendered exceedingly probable that the introduction of a heated blast in the manufacture of cast-iron has injured the softer irons, whilst it has frequently mollified and improved those of a harder nature, and, considering the small deterioration that the irons of quality No. 2 have sustained, and the apparent benefit to those of No. 3, together with the great saving effected by the heated blast, there seems good reason for the process becoming so general as it has done.' Respecting the specific gravity of hot blast iron, we may state that some years ago, Dr. Thomson carefully analyzed the chemical constituents of hot blast iron, and he found, as a general result, that the specific gravity of hot blast iron is greater than that of cold blast, and an average of several experiments showed that the hot blast increases the specific gravity of cast-iron by about 1-22d part. Dr. Thomson also found that hot blast iron contained a smaller proportion of carbon, silica, and aluminum than cold blast iron.

"We now come to what we have termed the commercial or trade influence of the hot blast on the quality of iron.

"The best English ironstone is the argillaceous or clay ironstone, and it requires the cold blast to work it in quantities. The iron produced is neither 'red short' nor 'cold short,' and is

thus never brittle, whether hot or cold. What is called 'cinder' is the refuse of the puddling surface. It contains a large percentage of iron combined with impurities that have been expelled by the puddler from good iron, or 'mine.' The power given by the hot blast in extracting the iron from amongst these impurities has greatly increased the production; but the produce is rendered very inferior by an admixture of this material. It is called 'cinder iron.' We do not assert that the hot blast injures the quality of the iron. As we mentioned before, its precise effect has not been ascertained with any precision. But we have seen that the hot blast may be used to extract iron from any material, from the best to the worst. The cold blast can only be applied to the best ore and fuel, it cannot be used to make 'cinder iron;' and thus the very name of 'cold blast iron' is to some extent a guarantee as to its quality. The introduction of the hot blast has thus been a great benefit as regards *quantity* of produce, but as regards *quality*, it has offered facilities for 'scamping' the work, of which, unfortunately, but too many have availed themselves. The hot blast has also been the means of permitting the ironmasters to use raw or uncoked coal, instead of the desulphurized coke. It is evident that more impurities are liable to be worked up with the iron when raw coal is employed. The Scotch coals are generally so unfit for coking that they often lose 55 per cent. in the process, and the introduction of the hot blast, by greatly economizing the coals there employed, has raised the iron manufacture of Scotland to its present importance. Within twenty years the make of iron in England has been trebled; in 1840 the total produce was a little less than 1,400,000 tons; in 1860 it was more than 4,150,000 tons. This progress, however, is more of a striking than solid character. Of the 1,400,000 tons of iron produced in 1840, 770,000 tons of this quantity was cold blast iron; of the treble quantity in 1860, only 150,000 tons were produced by the cold blast. Figures, however, do not give a true account of the produce of the iron manufacture. Mere quantity is a very rough estimate; quantity and quality combined ought to be taken into account. Double the resisting powers of the iron produced, and for many applications less than half of the quantity is required.

"The value of raising the temperature of the blast is thus another point upon which much difference of opinion still exists. As we have seen, some say that hot-blast metal is greatly inferior to cold-blast, in contradiction to others who assert the contrary opinion. The exact amount of economy of fuel effected by the use of this process is another subject of dispute. No definite data exist that would warrant our drawing conclusions as to its precise influence on the molecular structure and chemical constituents of iron. We consider that this great uncertainty is a disgrace to the iron manufacturers as a body; and without overlooking the fact that a strict inquiry into the matter would involve great expense and difficulty, we nevertheless consider it very extraordinary that the exact value of a process employed for the last 35 years, is still involved in obscurity. The fact seems to be that the manufacturers, on the one side, ignore the deductions of theoretical science; while, on the other, laboratory chemists refuse to consider the practical requirements of manufacturing on a large scale. The only means of arriving at the truth would be by the labours of a scientific commission, meeting the iron-makers on their own ground. The usual way adopted in England in encountering these questions, is to summons a host of witnesses before a Parliamentary Committee of Inquiry, and the culminating result of this expensive procedure is a voluminous blue-book, which is read by nobody. The evidence given is, no doubt, often very valuable in its way; but who is to separate the grains of wheat from the mass of chaff? This separation could only be effected by the light of science; not by orators from parliamentary benches, but by chosen men, taken from the forge, the laboratory, and the workshop."

In the above article we quite agree with the writer in saying, that much of the inferiority attributed to the hot blast pig is due to the amount of "cinder iron" worked up with the good pig, and this "cinder iron" contains impurities sufficient to contaminate large quantities of good iron. Were special attention directed to the complete purification of the iron extracted from "cinder," then "red and cold shortness" would so far disappear from much of the commercial pig. Upon the purification of such iron in "cinder," A. L. Fleury, chemist, Franklin Institute, Philadelphia, has published a circular in the "*Scientific American*," de-

scriptive of a new process of extracting good iron from "cinder," in which he states that he "has succeeded in extracting good wrought-iron and steel from the waste cinders of puddling and reheating furnaces, which have hitherto been considered a nuisance in their vicinity. He states that, from chemical analysis, he is assured that such cinders contain from 25 to 50 per cent. of iron, combined with sulphur, silica, phosphorus, and alumina, forming a brittle compound. Near the large ironworks at Troy, N.Y., thousands of tons of these cinders are spread over the roads, and in every 100 lb. there are about 35 lb. of iron. By reworking this cinder with lime and charcoal, iron had been extracted, but it was invariably red-short (brittle at a red heat), as the sulphur, silicon, and phosphorus remained combined with the iron. Numberless unsuccessful efforts had been made to work this cinder economically. Mr. Fleury states that the problem of extracting the iron from the cinder and removing the impurities, was solved by taking advantage of the chemical fact that unslacked burnt lime possesses the property of decomposing silicates during the act of being slacked with water. He mixed a proper quantity of powdered burnt lime, with fine ground iron cinder, wetted the whole with water, and exposed the mixture to the atmosphere. When this compound was dry, it was placed in a common puddling furnace, treated like pig iron, and 50 per cent. of wrought-iron was obtained. This product, however, was somewhat red-short, as it contained traces of sulphur, but the impurity—Mr. Fleury informs us—he afterwards extracted, by mixing a chlorine salt with the water which he employed to wet the lime mixed with the cinder; and a good quality of iron, we are informed, can be invariably produced when the operations are properly conducted. It is also stated that the cost of preparing the cinder does not exceed 2 dols. per ton, and the operation of smelting can be executed in puddling, blast, or other suitable furnaces. The invention has been patented in America and Europe."

The advantages of the hot blast system, however, are very great, and especially with the Scotch coal. Mr. Truran ascribes its economic superiority to two separate causes—

"The first is, that the heat thrown into the furnace along with the blast, *permits a corresponding quantity of coal to be with-*

drawn from the burden of materials, and a proportionate reduction in the volume of blast. The effect is seen in the augmentation of make, but not in any saving of fuel. The second cause is, that the reduced volume of blast, and the large amount of heat which it carries with it, cause a diminished consumption of fuel in the upper parts of the furnace, the result being that a quantity of fuel is saved at the furnace greater than what would be due merely to the caloric introduced by the blast."

The quality of different samples of cast-iron can be pretty well ascertained by the appearance of their fracture, those having a large crystalline appearance being of a soft and tough nature, those presenting a fine grey granular appearance being of a hard and brittle nature. The best test, however, is the application of the hammer and chisel or file in the hands of one who has practically worked in iron. The following is a test recommended by a writer in the '*Mechanics Magazine*' for ascertaining the quality of iron when in a melted state:—

"When melted pig iron is tapped into a ladle in moderate quantities, so that excessive heat may not prevent pretty close observation, it will sometimes be found to boil violently, sometimes its surface is calm from the first. Now, if this molten iron is allowed to stand a few minutes until it becomes perfectly quiet, and is then carefully skimmed clean, we shall find that a beautiful iridescence covers its entire surface, due to the constant breaking up of the extremely thin film of oxide formed on the iron. This iridescence, frequently called by moulders the 'pattern of the iron,' may, on close inspection, be found to consist of a multitude of many sided or rayed stars, in constant motion; breaking up and vanishing, and forming anew with the velocity of thought, and almost eluding the eye. It is a matter of extreme difficulty to determine the number of rays in each figure; we believe we are correct in saying five; *one* thing is certain that their shape and character is invariable with every species of iron with which we are acquainted.

"This much premised, we would call attention to what we are inclined to consider as a proved fact—namely, that the *size* of the different figures which make up the 'pattern,' in all cases, *depends* on the size of grain of the iron when in the pig. Thus, hematite, which is a large-grained iron, will, when melted, pre-

sent a large pattern. Fine-grained irons, such as the grey forge pig of some of the Staffordshire works, give an extremely small pattern. This distinction is, we understand, so well marked, that in some cases a glance at the melted iron will enable an accurate opinion to be formed as to the size of grain in the pig."

Coming now to the manufacture of wrought iron, we have heard of little novelty during the past year; but the puddlers' strike, which has raised the price of wrought iron to such a height, points only too plainly to the necessity of puddling by machinery, or superseding puddling altogether. Upon the subject of puddling by machinery the '*Engineer*' says:—

"The present attitude of the South Staffordshire puddlers, who threaten a stoppage, temporary at least, of the iron trade of their district, renders it more desirable than ever that puddling machinery be perfected and generally adopted.

"What is puddling? It appears to consist in stirring a quantity of melted iron, and in bringing each portion of the whole mass successively up to the surface. What is the object of puddling? Simply, by bringing each particle of the melted iron to the air, to allow the oxygen of the air to seize upon and combine with the carbon and silicon associated with the iron. Practically, it is only the presence of carbon and silicon which render iron fusible in the cupola, making it, as we say, 'cast iron.' When desilicatised and decarbonised (for the silica is always carried off first in puddling), the particles of the iron cohere so much more strongly than before that a much higher degree of heat is required to separate them—so high a heat, indeed, that the iron will burn before it will melt. Iron thus cleansed, we need hardly say, is 'wrought iron.' The primary object of puddling is accomplished by any means which will bring the particles of the melted iron successively up to the air, or, on the other hand, carry the air through the iron. Although not technically a process of puddling, the Bessemer treatment of iron gives much the same, if not the same, results. The difference, so far as there is any, in this respect, would appear to be that the Bessemer process cannot be interrupted, with a certainty of success, until the iron is thoroughly decarbonised or nearly so, whereas puddling is never carried quite to this extent. At the very high temperature at which the iron is kept in fusion towards

the end of the conversion by the Bessemer process, there is more or less burning, and the subsequent addition of 'spiegel-eisen' produces distinctive, although generally excellent results upon the product. Still there is a difference between Bessemer metal and puddled iron, and of such a kind that, thus far, the former is inapplicable to many of the purposes of the latter. Whatever may yet be accomplished in the mode of converting iron, we must retain the puddling process for a time longer. But it cannot be impossible, we should suppose, to contrive a machine capable of performing what the puddler now does laboriously by hand. It is true that his work is not altogether mechanical. He certainly has to use his eyes and to act with considerable judgment. But there are thousands of men who might readily be trained to the necessary degree of observation and judgment, although unfitted for the perspiring task of raking and balling. What is wanted is a puddling machine capable of doing the work, while the attendant, with a fair aptitude and some preparation for the business, supplies the observation and directing skill. Captain Warren, Mr. Tooth, and others have invented puddling machines, but they do not appear to have answered. Captain Warren proposed a revolving cylinder, lined with fire-bricks, and turning upon a horizontal axis oblique to its own. Melted iron, placed within this apparatus, would thus be churned from one end to the other with an energy corresponding to the speed of revolution and the obliquity of the axis of the cylinder. Mr. Tooth employed a cylinder so lined with fire-brick as to present alternate ridges and depressions along its internal length. This cylinder was put in revolution upon its own axis, which was horizontal, and the iron was thus successively carried up on one side and allowed to fall again. Fair results were claimed for this contrivance, two years ago, and it was especially urged that, instead of the usual consumption of 25 cwt. or more of coal per ton of pigs puddled, a very much less quantity was found to suffice. On the other hand, it was represented that many of the blooms puddled by this process were but little better than cast iron, and whether this be true, or whether from questions as to the validity of the patent, it was not thought expedient to push the matter further, the fact remains that little or nothing has been heard of the 'mechanical puddler' for the past two years.

Its action certainly did not resemble that of the puddler's hook, and this, we think, must be the starting point in designing any machine for the purpose. By the correspondence of the '*Mining Journal*,' it appears that Messrs. Dumeny and Lemut, iron-masters at Clos Mortier, near St. Dizier, have invented and set to work a puddling apparatus, which consists of an adaptation of mechanism to a series of ordinary puddling hooks. The description given is in very general terms, and leaves us unable to form anything like a judgment as to its real success. There must be many ways, one would think, of imitating mechanically the action of the puddling hook. Something like Schroder's evaporating pans, as employed on sugar plantations, would, if the discs were wrinkled or provided with projections of some kind, at least bring the iron well up to the air. Whether any material of sufficient strength could be found to stand the heat would require to be settled by experiment. The central shaft would require to be coated with fire-clay, ganister, or calcined silicate of magnesia, and might even require to be made hollow with a circulation of water through it. There is also a contrivance employed for whipping eggs and creams, in which apparatus a pair of radial arms revolving horizontally in opposite directions are provided with stirring pins, set much like the teeth of a rake. It would be interesting to know how far an apparatus of this sort, with its axis of revolution inclined in a greater or less degree from the surface of the melted metal, might be made to produce the effect of puddling.

"Not only are the ironmasters now at the mercy, so to speak, of the puddlers, but at the best the work of puddling is of a kind at which no human being ought ever to be employed. Besides its laborious nature, too, it is most unsatisfactory to be compelled to work upon such small masses of metal as are dealt with in the puddling furnace. Puddling furnaces cannot now be made larger than the size permitted by the range of the puddler's hook, and this must be light, and therefore short, in order that even a strong man may work it for half an hour or so in the high heat to which the puddler is always exposed. As it is, a 3 cwt. charge is about as much as he can manage at a time. The time will come, will it not, when the least charge will be as many tons?"

The difficulties to be overcome in puddling by machinery, we

think, are very great, since no machinery, however automatic, can incorporate *mind* in its actions.

A more feasible plan would be to supersede puddling altogether by a direct conversion of pure or wrought iron from the ore. The Bessemer process is not exactly a substitute for puddling, being in a measure simply a process of forcing the oxygen in contact with the metal in place of exposing the metal to the action of the oxygen as in puddling. The converting vessels reduce a quantity of cast iron to a state of wrought iron in a few minutes, the iron being kept all the while liquid. The additional heat required to keep the iron liquid during the process of decarbonization is obtained by the direct combustion of the carbon in presence of the oxygen forced into the converting vessels. The iron, however, by this process, although excluded from the air as much as possible, suffers considerable loss from burning. The direct conversion of wrought iron from the ore has of late received a certain amount of consideration, and abroad considerable success has attended such operations,—much of the foreign bar imported into England being obtained by this direct process. A description of one process of effecting such conversion is given in Truran's "Iron Manufacture of Great Britain:"—

"The production of wrought iron direct from the ore—the original mode of manufacturing—has engaged the attention of numerous practical and scientific men, and is practised to a limited extent abroad; but the attempts made to reinstate it in this country have hitherto been, commercially speaking, unsuccessful; and though the ores and fuels we possess are unquestionably superior to the foreign for this purpose, fusion in the blast furnace, and conversion into malleable iron by the puddling process, is pursued with all the bar iron now manufactured.

"The conversion direct into malleable iron dispenses with the blast furnace and appendages, and the intermediate processes of refining and puddling, and if successful, should result in the production of a finished bar of superior quality, with a smaller consumption of ore at a proportionately lower cost. In all experiments on converting on this plan, the bar is of inferior quality, the consumption of ore larger, and the cost of production augmented over that attending the manufacture by blast furnaces and refineries. The causes tending to produce this difference between

the results of theory and practice are numerous, but will receive from us only a brief notice.

"The ore to be converted is ground to a coarse powder, and in mixture with a quantity of carbonaceous matter similarly divided, is charged into a reverberatory furnace not unlike the ordinary puddling furnace. The draught is forced to the production of a high temperature, reducing the ore to a semi-liquid state, when, by dexterous manipulation on the part of the operative, metallic iron is separated from the extraneous matter, balled up, and shingled as in the usual manner. The theory of this operation is simple. The carbon of the carbonaceous matter is consumed by uniting with the oxygen of the ore, and the metal is left free to agglutinate into a mass. The Beaufort black band was thus converted into malleable iron, though after a few experimental trials the operation was discontinued. The principal objection to its extensive adoption, seems to lie in the difficulty of effecting a complete separation of the extraneous metalloids of the ore. In the blast furnace it is accomplished by mechanical subsidation in the hearth, and the extraction of the metallic iron from the low level; in the direct mode of manufacturing it is effected to a certain degree, by severe manual labour, which being skilled, commands a comparatively high price, and materially enhances the expenses incident to the process.

"The prolonged exposure of the metallic iron to the oxydizing influence of the flame and gases during the process of separation from the alloyed matters, results in a considerable waste of metal, and accounts for the comparatively inferior yields.

"To obviate this loss, and to economize the fuel and labour demanded, the ground ore and carbonaceous matter have been subjected to the necessary heat in a closed supplementary chamber, whereby the combustion of the carbon is slowly carried on at the expense of the oxygen of the ore, but at a sufficiently low temperature to avoid oxydizing the mass. From this chamber it is drawn as required into the furnace, balled up and shingled, the deoxydized ore agglutinating without undergoing the puddling process, which being essentially a decarburizing process is unnecessary with the minimum volume of carbon consumed in the deoxydation of the ore in the close chamber.

"Ground carbonaceous ore may be substituted for the car-

bonaceous matter, and mixed in the necessary proportions with the same ore calcined, or, with raw hermanite, the deoxydation can be effected without the usual ground coal, at a corresponding reduction in the expense. In this respect, the possession of ores of such varied character gives the ironmasters of this country an important advantage over their foreign compeers; and, should this mode of manufacture, at some future day, become more profitable than at present, would enable them to maintain their supremacy in the trade. The rich carbonaceous ores of Scotland or Wales, mixed with the hematites of Lancashire or West Cumberland, or other similar ores, reduced in suitably constructed furnaces, may be converted into malleable iron, at costs considerably under those incurred with the blast furnaces and subsequent decarburizing system.

"With existing modes of operation, the advantages of direct conversion are principally confined to the comparatively small capital required to establish the manufacture, which may be on the smallest scale, yet, to a corresponding extent, profitable. Hence it is especially applicable to new districts, requiring an immediate small supply, and to countries deficient in the capital necessary for carrying on operations on a large scale with blast furnaces, and attendant refining and puddling furnaces. To establish on a sound basis works consisting of blast furnaces, refineries, puddling forges, and rolling mills, a capital of at least £20,000 per blast furnace, where there are four, is required; with a fewer number, more. In the direct mode wrought iron in proportionately smaller quantity may be manufactured, with a capital of only one-twentieth, or one-thirtieth of this sum. In this respect, therefore, it is more advantageous, and may consequently, under certain circumstances, merit the preference over the established system."

Proceeding now to the consideration of steel. Beginning with the descriptive part of this manufacture, we cannot do better than give the following interesting and valuable paper read before the mechanical section of the British Association, by Mr. T. Spencer:—

"The history of the manufacture of steel in this locality commences at a very early period; for we find that, probably 300 years ago, a colony of Germans settled at a place on the river

Derwent, within a few miles of this town, and, according to tradition, there established this branch of local industry, where they also attained some celebrity as manufacturers of swords and edge tools. The names of these immigrants who, it is stated, took refuge in this country, that they might enjoy religious liberty, were Ole, Mohl, Vooz, &c., &c., and some of whose descendants still reside in the village where their ancestors originally settled, the names being now Anglicised to *Oley, Mole, &c.* The name of this village is Shotley Bridge, and in the wall of an old two-storeyed dwelling-house, the original materials of which are hidden under a coat of 'rough-cast,' there still exists a stone above the doorway with an inscription in bad German, to the following effect:—DES. HERREN. SECEN. MACHET. REICH. OHN. ALLF. SORC. WAN. DVZVGLEICH. IN. DEINEM. STAND. TREVV. VND-LLEISIC. BIST. VND. DVEST. WAS. DIR. BELOHLEN. IST 1691, of which the following is a free translation, showing that the original importers of the steel manufacture to the district were probably good Lutherans, who had suffered persecution for conscience sake:—'The blessing of the Lord makes rich without care so long as you are industrious in your vocation and do what is ordered you.'

"But there is a much earlier record of these German immigrants than the above; the parish register at Ebchester church containing the following entry, by which it will be seen that the name even then had undergone a change:—'Elliner, the daughter of Mathias Wrightson Oley, was baptized on the 17th day of June, 1628;' and shows, also, that the grandfather of the child then baptized had probably married into a family of the name of Wrightson, at that time resident in the neighbourhood, as appears by several entries in the parish register of the period, clearly marking a third generation.

"In all probability the next works of this nature established in this locality were those of Sir Ambrose Crowley, who is described as an ironmonger, and afterwards Alderman and Lord Mayor of the City of London, and who appears to have commenced a manufactory at Winlaton Mill in the year 1691. The names of Landells and Chambers are mentioned as being in this trade at an early period, after whom came Cookson, Spencer, and others, whose works are carried on at the present time.

"The manufacture of steel, as at present carried on in this

district, comprises the following descriptions:—Blistered, shear, spring, and cast steel, to produce which the following materials are required: iron, carbon in the shape of charcoal, manganese, coal, coke, fire-bricks, and fire-clay—of these the iron and manganese are imported into the district, the former for the best qualities of steel being brought from Sweden. The charcoal, coal, coke, fire-bricks, and fire-clay are produced in almost inexhaustible quantities and of most excellent quality in the immediate neighbourhood; a small proportion of fire-clay, however, having to be brought from a distance for admixture with that found in the locality.

“The mode of manufacture in use here is that known as the cementing or converting process, the furnaces used being large enough to contain from 10 to about 23 tons of materials at one time; this material consists of selected iron, and known to the manufacturer as being most suitable for the purpose for which it is ultimately intended. It is placed in the cells of the furnace with bruised charcoal in alternate strata, the whole being covered with a vitreous material to effectually exclude the air, and heat is applied for a period of about eight or ten days, according to the degree of carbonization required. The mass is allowed to cool for several days, and the bars are then taken out in the form of blistered steel. The change that has taken place in its structure since it was placed in the converting furnace is very marked, for instead of now being of a fibrous nature it is quite of a crystalline character, and it must be reduced or drawn out under rolls or heavy hammers to bring back to it something of its former nature. It is, however, used in the blistered state for many purposes, such as for welding into hammer faces, and for welding to iron for edge tools and for spades and shovels, although cast steel is now fast superseding its use even for these purposes. Spring steel is made by simply reducing with rolls the blistered bars, and shear steel is made by repeatedly drawing down and welding the blistered bars. This last-mentioned description is also being fast superseded since the introduction of mill welding Speast steel.

“The most important of what may be termed the secondary processes of this manufacture is that for producing cast steel, and it is (among the old methods of making steel) of the most

recent introduction. Cast steel is different from all the other descriptions of steel in its fineness of grain, greater strength, and its homogeneity. The first steel used in this country partaking at all of the nature of this description of steel was the Indian Wootz, which was much prized by users of steel, especially by the makers of dies for coining presses, who, it is said, paid the almost fabulous price of five guineas per pound for it. The discovery of the English method of making cast steel is due to Benjamin Huntsman, of Attercliffe, who appears to have arrived at it by a series of experiments. He was a clockmaker, and desired to improve the quality of steel for clock-springs. He was born in some part of Lincolnshire in the year 1704; and, although his family are said to have been German, he must have become thoroughly Anglicised, as he was a strict Quaker. In all probability, this discovery was made before the year 1760, as it had become public previous to his death, which took place in 1776, at 72 years of age. This process was first introduced into this locality by the late firm of Messrs. Crowley, Millington, and Co., in the beginning of the present century, probably about the year 1810, who were next followed by Messrs. Spencer, of Newburn. Afterwards, Messrs. Cookson and Co. erected cast-steel melting furnaces, at their works at Derwentcote; and within the last few years, Messrs. Fulthorpe and Co. of Dunston, commenced this branch of the steel trade. Cast steel is produced by breaking the blistered steel into small pieces, and placing the same in crucibles or melting pots, capable of containing 36 to 40 lb. weight each, two of which are placed in each melting furnace. A plentiful supply of coke is now filled into the furnaces, and by the aid of a strong draught of air, an intense white heat is obtained and kept up for three or four hours, according to the nature of the steel required. When it is ascertained that the steel is perfectly melted, the crucibles are taken out and their contents poured into iron moulds conveniently placed near, and left to stand until in a cool enough state to be taken out as cast-steel ingots. These ingots are afterwards reheated and hammered or rolled, or it may be both hammered and rolled, according to the description of article for which it is intended to be used. To produce large ingots, a number of crucibles containing liquid steel are brought out of the furnaces,

quickly following each other, and a continuous stream is kept flowing into the mould. There is scarcely a limit to the size of ingot that may be made in this way, as was evidenced by the monster block of steel exhibited by Krupp, of Essen, at the International Exhibition, in London, last year; but great risks are run of getting an unsound ingot, as the least delay in getting out every crucible of steel in perfect order might cause a cessation of the stream, and thus make an unsound casting. In the year 1839, a great improvement was made in cast steel by Josiah Heath, by the introduction of manganese. Having described the various processes that the several different kinds of steel undergo in its manufacture, it may be useful to notice some of the new methods that have been tried in the neighbourhood.

"The method of making steel by the cementing or converting process, as already described, may be called the indirect method, because the object of the process is to deprive, in the first instance, the pig iron of the whole of its carbon, making the product as nearly as possible a pure malleable iron, and afterwards imparting to it again the necessary quantity of carbon to make it into steel. The new methods seem to aim, for the most part, at making steel by a direct process, without depriving the pig iron of the whole of its carbon, and without reducing it into a malleable iron condition. This is effected by extracting a large portion of carbon, but taking care to leave in a sufficient quantity to make steel, the object being to save the great waste of metal attending the puddling of iron, as well as the actual cost of that process. Of these last methods the Uchatius process is one that was extensively experimented on a few years ago at the Newburn Steel Works, and the following is a short description of the manner in which the process was carried on. Pig iron, of a first-class quality, was melted in a reverberatory furnace, and run into a tank filled with cold water, where it was reduced into granules; this granulated cast iron was mixed with pulverised oxide of iron and some alkaline earths, and the whole put into the ordinary steel melting crucibles, and then placed in the furnaces, to which heat was applied in the usual way until it was brought into a fluid state. By this method it was thought that the degrees of hardness of the steel was capable of being regulated by *the size of the granules*, and by the quantity of oxides used; but

after a great number of experiments, at a cost of little under a thousand pounds, on attempting to work it in large quantities, it was found that the product was so uncertain in the qualities necessary to good steel, that the process was altogether abandoned. This irregularity of the produce was probably caused by the uncertain quantity of carbon in the pig iron used.

"A method of making 'puddled' steel has been tried in this locality, but without success. This process was a patented invention of Riepe, a German, and consists in puddling cast iron in a furnace constructed specially for the purpose, until it is observed to be in the condition of steel. This state is found to exist when a particular form of bubble appears on the surface of the metal.

"The Bessemer process of making steel has also been introduced into the district at Tudhoe, near Ferryhill, but with what success the writer is not able to say. The operation, as is generally known, consists of blowing atmospheric air through a mass of melted cast iron until the carbon and the whole of the impurities of the iron are burnt out of it. This process has been so ably described by Mr. Bessemer himself, at the meeting of the British Association, at Cheltenham, that it is unnecessary to give a detailed description of it here; but it may be mentioned, that he commenced by extracting only a portion of the carbon, intending to leave in a sufficient quantity to produce steel, but the difficulty of adjusting the exact amount finally led him to extract the whole, and afterwards restore the exact quantity requisite by adding a measured amount of highly carbonized cast iron. Experiments in making cast steel from the Taranaki sand from New Zealand, and also from another similar sand from the coast of Italy, have been tried at Newburn with a result of getting an excellent quantity of steel; but, although yielding about 51 per cent. of metal, the cost of its production, without including anything for the sand, was so great that it would not answer commercially. It may be mentioned that this description of metallic sand appears to possess the remarkable property of not becoming oxidized when kept in a moist condition; and the writer would call the special attention of chemists and metallurgists to the fact, with the view of arriving at (what would be an invaluable discovery) the production of iron or steel that

would not be subject to the destroying action of the oxygen of the atmosphere.

"The articles manufactured from steel in this locality are very numerous, amongst which may be mentioned railway axles, tyres and springs, piston rods, motion bars and files for engineers' use, rings for Blakeley guns, shot, &c., the great bulk of tonnage being railway springs of various kinds: buffing, bearing, and traction in the laminated form, as well as the volute spring originally made in this country at Newburn, and of which there have been many hundreds of thousands made the last few years. The rings supplied for guns made in this district have been pronounced by the consumers superior to any others. A firm, in this locality, has been appointed makers of springs for Mr. W. Bridges Adams' patent for the application of circular springs between the tyre and the frame wheel for all kinds of rolling stock on railways; and it is stated that springs applied in this manner effect an increased durability in Staffordshire tyres of 50 per cent. over Krupp's cast-steel tyres without the springs.

"The estimated annual value of the steel manufactures of the district is about £100,000, giving employment, at the present time, to about 300 persons, and consuming annually about 15,000 tons of coals. There are in the district nine converting furnaces and 52 cast steel melting furnaces, of which the following is a list of firms having those furnaces:—Messrs. John Spencer and Sons, Newburn, 6 converting and 36 melting furnaces; Messrs. Cookson and Co., Derwentcote, 1 converting and 6 melting furnaces; Messrs. Fawcus and Co., Swallow, 2 converting and 6 melting furnaces; Messrs. Fulthorpe and Co., Dunston, no converting and 6 melting furnaces.

"As far as can be ascertained, it would appear that the number of persons employed in this trade in 1838 would be from 70 to 80, and the weight of steel produced annually at that time would be about one-ninth the quantity now produced. The prices of steel range from about £18 to £112 per ton, according to the description, the quality, and the size. This district is highly favourable for the development of the manufacture of steel of the best quality, owing to the facility and cheapness with which a supply of iron can be obtained from Sweden—freights frequently being as low as 3s. 6d. per ton—and also owing to an

abundant supply of cheap fuel and labour in the neighbourhood. The business requires, however, the most vigilant attention of thoroughly practical and experienced persons in its management to attain any considerable amount of success."

The Germans seem to be far ahead of us in producing steel in large masses, as the blocks sent to the 1862 International Exhibition fully illustrated. Owing to the system of melting cast steel in crucibles considerable difficulty and danger attended the 'pouring' of their contents in regular and quick succession so as to secure a sound and homogeneous casting. Each crucible was limited in weight, not being able to contain more than 100 lbs. steel, and this required two men to handle it. The following is an abstract from an article translated by the '*Practical Mechanics' Journal*' from the '*Kölnische Zeitung*:'—

"The first manufactory of cast steel was established in Sheffield, in the year 1740, by Huntsman; and, till this century, he had no successful followers, except in England. The exorbitantly high price of steel was, meanwhile, a strong inducement to attempt its production elsewhere. Germany was not behind hand, and has had the happiness of possessing men, who not only imported the English mode of manufacture to their own land, but, by improvements and new inventions, raised it to such a height that, in the present day, the German manufacture of cast steel surpasses that of all other countries. England succeeded in producing cast steel of such superior quality, that, in this respect, no material advance has been made upon it; but the size of the individual pieces, which the manufactory furnished, was so small, that, necessarily, only tools, weapons, and fine articles of all kinds, were made of cast steel. There appeared, in the London Exhibition of 1851, a block of cast steel of almost 5,000 lbs. weight, exhibited by Herr Krupp, of Essen. The astonishment which it produced was general and great; it could not have been greater had a skilfully cut diamond, of a pound weight, been produced; and such a gem would have been of much less importance, for, to the existence of a block of cast steel of several thousand pounds weight, was attached the possibility that this strong material might no longer be limited merely to the fabrication of chisels, and files, and other small articles, but could be used for machinery, and the construction of railroads and carriages. That block

opened a new career to cast steel, while it proved that no limit to its size existed, save in the extension of the furnace and other plant; and that this limit can be widely stretched, Herr Krupp demonstrates by the block of 40,000 lbs. weight sent to the present Exhibition.

"In the English factories, as well as in Krupp's foundry, only blocks of the most simple form were, and are still, produced, the steel melted being poured into cast iron moulds. These blocks acquire, in process of working, the same character as finished bars (*fertigen luppen*) in the manufacture of iron, which can only be enlarged by the welding on of other pieces, and, like these bars of iron, the simple steel blocks are fashioned into objects of varying form and size, by hammers, rollers, and other mechanical means. This kind of steel manufacture has been marvellously improved in Krupp's work. He has gained for himself the double merit of producing in his melting works, steel blocks of the best quality, and of every desirable weight, and of afterwards fashioning them in his forges, and mechanical workshops, into objects which none before him had ever made of cast steel. In addition to many other things, Krupp has furnished cast steel axles for marine engines, locomotives, and rail-carriages, and cannon, from the lightest to the heaviest calibre. Even a square steel block is fashioned by mechanical means into a round wheel-tire of one piece, and without being welded. All that can be made from a simple steel block, by the agency of mighty hammers, and turning, boring, and planing, is executed by Krupp with a skill as yet unsurpassed.

"By this method of fabrication, those properties of cast steel, which it possesses in common with malleable iron, are turned to the best advantage; but the other qualities found combined in it—its fusibility, and capacity for *casting*, are not fully brought forward. Perhaps many a reader has already remarked this, and inquired, with surprise, *why* only simple blocks are cast from the molten steel, and not, as with cast iron, all those objects which, owing to their complicated form, are forged with difficulty. It is, apparently, quite as simple to employ cast steel in the same manner as cast iron; and the great advantages to be gained by so doing lead to the presumption that attempts have not been *wanting*, since the first cast of molten steel was seen; but all

attempts were long unsuccessful. No cast forms, properly so-called, could be obtained from steel by any of the methods in use, with other metals. A new discovery alone could reach the goal.

"Of all who strove with this aim, one only was successful: Herr Jacob Mayer, the founder of the Bochum Steel Manufactory, and the present scientific director of these works, for the manufacture of cast steel.

"With the untiring perseverance of years, and the energetic faith of a man who is urged forward by the consciousness that he will at last overcome all difficulties, Herr Mayer has completed his task, and discovered the method and way to make, in steel, true castings, answering every purpose. Thus an important service has been rendered to science, for now only is it possible to profit, in an efficient manner, by the great advantages which cast steel unites in its double nature. Many objects which prove too weak when made of cast iron, and which are very expensive, and, perhaps, still defective when made of welded steel, or malleable iron, can be cast directly from steel, in consequence of Herr Mayer's discovery, and are not to be surpassed in excellence. Again, things which are first cast, can be subsequently prepared by hammers and rollers. While, for iron, casting and forging are two completely separated regions, Herr Mayer has, for cast steel, thrown down the partition wall, and summoned the former to the assistance of the hammer and roller. Of course, steel casting has narrower limits than iron casting. The extraordinarily high fusing temperature of cast steel, and its imperfect liquidity when melted, hinder the casting of as fine objects from steel as from iron. The boundary may be somewhat enlarged, but cannot be entirely removed. It is, however, practically, of little importance, and is no hindrance to the employment of cast steel for many useful purposes. Some specimens, forwarded by the Bochum Company, to the London Exhibition, deserve especial notice; and we must be allowed to speak of them in particular. Relative, however, to the peculiar manipulation of these castings, nothing can be communicated, for this is the secret of the Bochum Foundry.

"Church bells were the first castings which Herr Mayer attempted with his new method. When these were first exhibited

in Paris, in 1855, their motto, 'May their first chimes be peace,' was not fulfilled; for a violent controversy arose about the material itself; and the question, whether they were steel or cast iron, divided the men of the department into two hostile factions. A mighty authority (ruled by the thought, *I am the manufacturer of steel*) would not allow that they could be cast steel bells; but Herr Mayer incontestably proved that they were so by breaking one of them. The jury awarded the large gold medal of honour to the Bochum Company; opposition was silenced; friends acknowledged, and adversaries could not gainsay, that the discoverer of steel had a formidable rival in his territory. Since then, many hundred steel bells have been cast. The advantages which the new bells possess over the old (which do not surpass them in clearness, or loudness of tone) are greater durability and strength, with nearly the same size and form, and well nigh half the expense. This last circumstance has enabled many poor churches to rejoice in the chime of a bell. The Bochum Company exhibit in London a steel bell of $8\frac{1}{2}$ feet in diameter, and nearly 20,000 lbs. weight. 'Let her name be Concordia.'

"The next important application of Herr Mayer was in favour of railways. The wheels of rail-carriages and locomotives, like those of common roads, are secured with a tyre, only necessarily much stronger. They are usually 2 inches thick, and 5 or 6 inches broad, and have, in order to prevent their running off the rails, a flange on one side—*spükrantz*. Formerly, wheel tyres were constructed of iron or puddled steel. Both these materials permitted no other mode of fabrication than bending into the wheel tyres, a straight bar forged for the purpose, the ends of which were finally welded together. The weld is the weak point of the tyre, and, on account of the great danger connected with its fracture, has absorbed much attention. Tyres, without a weld, were long the desideratum of railway constructors. Herr Krupp was the first who gratified their wishes, and furnished unwelded tyres of cast steel—the best material for the purpose in existence. His method of manufacture, so far as it is known, is as follows:—First, a long flat block is cast; this is hammered out; a long, slot-like hole is pierced along through the middle, and, by wedges, it is gradually extended, while hot, into a ring; and, lastly, it is made round on a central roller (*centrir walze*)

passed through it. Instead of this difficult method, another is employed in the Bochum works, by which the production of steel tyres is much simplified. The discovery of Herr Mayer renders it possible to cast the tyre with the flange upon it; this, like every other casting, must be freed from the mould; in this state, it has only half the finished diameter, and is enlarged by the stretching it undergoes between the central rollers; these are driven by a nearly 300 horse-power engine at Bochum. This Bochum method of wheel-tyre manufacture is a fair example of the extent to which the preparation of steel can be facilitated by the preliminary operation of casting; in fact, casting and forging should go hand in hand. On the German railroads, thousands of Bochum tyres are already in use, and highly approved of. Among those sent to the London Exhibition, is one of the unusually large diameter of $9\frac{1}{2}$ feet, and another, which has been bent close double in the cold state, to show the toughness of the material. As cast steel tyres (on account of their great durability, and consequent less wear and tear) are of the greatest importance to the railway interest, the companies have much reason to thank the Bochum Company, since, by their method of production the price has been reduced by one half.

“To secure the tyre on the wheel frame, the contraction, consequent on the cooling of the tyre applied while red hot, is made use of; tension ensues, and the strength of the wheel depends on the care with which the fitting is adjusted. This initial strain exposes the tyre, under certain circumstances of temperature, to the danger of bursting. The tyre is also rendered thinner by the wear of the brake, and continued rolling in use, expands and loosens the tyre from the wheel. These evils might be obviated, and cast steel wheels brought to the highest perfection, if they could be fashioned in a single piece. In any case, this is a very difficult task for the founder, and, till recently, no steel block was ever changed by the hammer into a wheel. But the inventor of castings in steel has succeeded in casting, by his own method, a railroad wheel, in which the tyre, spokes, and nave, are one single piece. This cast steel wheel is the best of all wheels yet invented for railway carriages, and it would be difficult to surpass it. It is (if not in first cost, at least in use) cheaper than ordinary wheels, provided with steel tyres; and it

has the great advantage of being strong, light, and needing no repairs. The Bochum wheel is exclusively the work of steel casting, and neither hammer nor roller is used in its fabrication. When taken from the mould, and freed from the sand, it is carefully annealed for the removal of any internal strains (*spannung*) due to contraction, and then completed with the assistance of the boring and turning lathes. In the spring of 1860, the Bochum Company first came publicly forward, and proved by comprehensive experiments, in the presence of a large assembly of railway contractors, the advantages and superior strength of this new manufacture, which soon became extensively employed on the German railways. In an International Exhibition, this invention appears in London, now, for the first time. The Bochum Company has sent thither two cast steel axles, with wheels attached; one pair of wheels is just as it would be furnished to the railroad; but the other is turned and polished, and shows, by its unblemished surface, how completely Herr Mayer has overcome the difficulties of moulding in steel, and succeeded in producing a clean and solid casting. Besides these carriage wheels, there are two locomotive driving wheels exhibited, in which the bosses for the shaft and crank pin have been also cast; steel wheels, for locomotive tenders, have been in use for some time, and have surpassed all expectations. It has been the fate of many a German invention to meet with its first honours in a foreign land, or to be plundered by strangers; but a happier destiny is allotted to steel casting. The Bochum Company has the means of keeping the invention on German ground, and enabling it to take root, and come to perfection, on the spot where it first saw the light. Their great foundry, in which every kind of cast steel is manufactured, has undertaken, as its principal business, the supply of articles for the railroad trade. In addition to these articles, the Bochum Company has furnished cast steel axles, and springs for locomotives, and railway carriages, of superior excellence. Its extensive workshops are furnished with the best tools and furnace apparatus; and, by their aid, and the toil of upwards of a thousand men, as much as 40,000 lbs. of cast steel are daily produced and manufactured.

"Amid the treasures and splendour of the London Exhibition, the contributions of German steel have been, by many visitors.

scarcely remarked; and yet they are of great importance, and point to one of the most remarkable advancements of this age, in the working of metals. This progress is more important, because it concerns *steel, the material which is destined to take the place of iron, as the man springs up from the boy.*

"Great as is the progress already made in Westphalia in steel manufacture, Sheffield will, we believe, run her hard in the race now beginning; and aided by the Bessemer process, which, we strongly are of opinion, will in the end be found greatly superior to the puddling one—for steel, at least; we predict that we shall far surpass our German rivals in magnitude and facility of production of steel in great forged or cast masses; and, we hope, also in superiority of quality.

"Already, along the line of the Midland Railway, at both sides, where it passes through Sheffield, manufactories of the largest class have sprung up, for the production of heavy steel; amongst these, one of the most remarkable is that of Messrs. Brown & Co., Atlas Works, who are engaged in the production of soft iron armour plates by the rolling process, as well as steel. They have two converting vessels, upon the Bessemer patent, at work, each producing 4 tons of cast steel at each operation; with the two, they can produce 24 tons of steel a-day. Mr. Bessemer himself, at his own works, upon a somewhat less scale, produces a large quantity; and Messrs. Cammel & Co., Cyclops Works, are at present constructing very large new works specially for Bessemer cast steel, of the heaviest class. Nearly the whole of the steel now made by this process is subsequently forged into axles, shafts, cranks, gun moulds, etc.

"Sound steel castings, of finished objects, are, at present, not attempted to be made, by pouring directly from the Bessemer converting vessel; the mass of metal in this, as may naturally be expected, appears to be *boursoufflé*, more or less, and, probably, is even in act of evolving gases, that make it porous. But uniformity of chemical constitution of the metal, to the extent of the large capacity of the converting vessels (say 4 tons in one mass) is insured. This might be run into thin ingots, broken up, and melted again, for steel castings, in crucibles, as by Krupp and Mayer, or in some still better and more fuel-and-labour saving way.

"All that is wanted, in fact, now, to enable steel castings to be made quite as good, if not better than the German ones, of any size, and at a greatly reduced price, is an air furnace, suited to melting the steel in large bulk, and without deterioration of its quality."

The Emperor of the French has with considerable sagacity devoted large sums of money to the production of a reverberatory furnace, according to the invention and designs of M. Sudre, which is said to have been capable of fusing steel in large masses, and thus giving facilities for the production of heavy castings in steel.

The following is an abstract of a description of such furnace, which we quote from the '*Practical Mechanics' Journal*':—

"The methods of M. Sudre appear to have been devised as early as 1857 or 1858, and have been patented in Great Britain, as well as abroad; the date of the British patent being 31st December, 1858, (No. 3007) sealed 29th May, 1859; a communication to John Henry Johnston, London; and rather more than a year appears to have elapsed, before the inventor succeeded in arresting the attention of his own Government, so as to be enabled to commence his trials on a great scale in October, 1860. He had previously held a position upon the '*Chemin du fer du Nord*,' and made experimental researches on the fusion of steel in its forges.

"M. Sudre's discovery rests upon the combination of three distinct inventions or applications, viz., a method of constructing a reverberatory furnace, producing, with pit coal, a heat sufficient to melt cast steel, without destroying itself. A method of economising the heat of this furnace, by preliminarily heating the steel to be melted, near to its fusing temperature, without injury to its quality; and a method of protecting the steel, as soon as it is placed in the reverberatory furnace, from all injurious action of the gases, etc., passing above it, or otherwise, both before and after its fusion upon the hearth of the furnace.

"The furnace was perfectly successful; but experience in its use, and some suggestions due to the acuteness and science of M. Sainte Claire Deville, developed some points in which it might be improved. The second furnace differed from the former *only in proportions, and in some structural details, to which we*

shall allude hereafter. The furnace consists of the usual grate of fire bars, separated by a bridge from the hearth, and that separated by a second and contracted bridge, from an oven, in which is placed a large muffle, or earthen retort. The flame from the fuel passing over the first bridge, and deflected by the low arch above in the usual way upon the hollow of the hearth, passes on over the second bridge, envelops the muffle, and finally passes off, through a descending and horizontal flue, to the chimney stack—a damper being interposed.

"The chimney stalk at Montataire, into which the furnace drew, was about 85 feet in height, 5 feet square inside at the base, and 3 feet 8 inches square at top, and three or four puddling furnaces also worked into it, during these experiments.

"The draft of M. Sudre's furnace, however, is not dependent wholly upon the ascensive power of the stalk, and this constitutes one of its main peculiarities. It is supplied by a forced blast from a fan, delivered into the closed ash pit. The fan employed was about 33 inches diameter, and 14 inches breadth of blade, and ran 1,200 to 1,500 revolutions per minute. The front of the ash pit is closed by a plate, removable for the purpose of getting out the ashes, after one or more fusions. The hearth of the furnace is so formed that the steel, when in fusion, can be tapped out, through a lateral aperture, opening into the bottom of the hearth, provided with a moveable iron shoot lined with fire clay, hooked on to the peculiarly formed side plate of the furnace mounting. This is stopped by a plug of tempered infusible clay upon the end of the ordinary *bott stick*, such as is commonly used for the like purpose in iron foundry cupolas.

"Great care and precaution were employed in the formation of the bottom of this hearth, whose capacity was that to contain nearly 1,800 pounds of liquid steel, with sufficient room for flux, etc.

"It was formed of one mass of very carefully beaten and tempered clay, formed in place to shape, over a layer of dry sand, covered with thin millboard on top, (which, when reduced to charcoal, was expected to leave perfect freedom of contraction to the sole of clay) the sand bed being laid on courses of bricks on *the flat*. The material for the sole was formed of one-fourth

tempered infusible clay of Andennes, worked up with great care, with three-fourths of like clay previously baked, and the masses reduced to powder, and sifted to fragments of about one-eighth inch in diameter. The object of all this care was to prevent the fluid steel from finding its way down below the sole of the hearth, or the latter being acted on by the protecting flux employed.

"In the second furnace employed, these precautions were in part neglected, and the sole was formed of fire brick of the same clay, but, as it proved, with disadvantageous results; and the result of experience has caused M. Sudre to propose for his future furnaces, soles formed by the potter, in each a single piece of infusible clay, baked, and laid into place on a bed of sand. The first experimental muffle was formed of fire brick, but this was not found to answer; and a couple of earthen coal gas retorts, laid side by side, and supported on pilarets of bricks, so that the draft circulated beneath as well as around them, were substituted; these answered tolerably, though not sufficiently infusible, and found liable to crack, and so to let in air to oxidise the steel within.

"M. Sudre in his last furnace employed such retorts, laid upon a solid sole of fire clay, and coated all over above, with a considerable thickness of the same, so that the flame, &c., only played above them.

"In this furnace, too, he remedied some other inconveniences found in the first. Thus, for the fire clay *plugs* (*obturateurs*) in iron frames, with which the apertures of the first furnace were closed, and which were found to expand and stick fast, and even to get soldered into their places—he substituted the ordinary slab of fire tile in a balanced sliding vertical frame, as usual in puddling furnaces, and the two bridges were made hollow, the air spaces through each passing right out through each of the side walls of the furnace, so that any cracking or escape of steel here, could be at once seen, and guarded against by ramming in dry sand into the air spaces.

"The main other difference of this second furnace from the first, consists in the lengthening the whole considerably. This was due to M. Sainte Claire Deville, who remarked with the first, that the point of greatest heat was beyond the second

bridge. It is indeed obvious, that a reverberatory furnace with a forced draft, must have this point '*le coup de chalameau*' thrown further forward beyond the bridge, as the draft is stronger.

"The dimensions of every part of these furnaces, the special precautions adopted by him in every detail, the results obtained, even the accidents and mistakes and tentatives through which this, like every other great improvement, has passed, are minutely recorded by M. Sudre, with honesty and intelligence, in his valuable memoir; but, to the original, we must refer those who take a direct interest in the subject, as occupying too much space here to transcribe.

"We pass therefore to some explanations of the principles upon which his methods are based. It has been known since the researches of Dr. Robinson's (of Armagh) early years, to be found in the Transactions of the Royal Irish Academy, that as high a heat can be produced by a draft furnace, as by one urged by blast; that the only difference as regards the maximum temperature attainable, is *one of time*. The blast furnace arrives within a few minutes, at a temperature that the draft or wind furnace may take hours or days to attain. But upon this question of *time* depends, *cæteris paribus*, that of the endurance of the furnace itself; whether, in fact, if the heat be sufficient, the matter exposed within the furnace be alone melted, or with it, or before it, the furnace itself be melted down.

"It was by proving and taking advantage of this truth, that Dr. Robinson was able, quite thirty years ago, to fuse platina in a small blast furnace, using as fuel the pure hard anthracite of the Kilkenny coal field; and with which he attained a temperature that certainly has never since been exceeded with any solid fuel. It is true that, as Dr. Wollaston (who was present at some of these trials) showed, the magnesia of the crucible acted slightly on the platina, to produce an alloy more fusible than pure platina itself.

"This then is the first object of M. Sudre's ingenious combination. By applying forced blast to an air furnace with the reverberatory hearth, he is enabled, after bringing up by *air draft only*, the heat of the whole furnace as high as its materials will safely bear, then, at the right moment, by converting the

natural draft into a forced blast, he can within the shortest possible time—and therefore with the least possible injury by melting of his furnace—bring it up to the extremity of heat necessary to bring the steel into fusion. But further, the steel itself must be brought to such a preliminary state of high temperature, that it shall offer the minimum of resistance to the fusing power of the furnace thus urged to its highest point; in other words, cold steel must not be put into the hearth of the furnace, but steel that has been *already heated* up to the highest point at which it can be handled with safety, and freedom from any serious amount of oxydation during the moments of transfer. With this view, he employs the waste heat of his furnace to heat the muffle, in which close oven heated all around, but having no communication with the interior of the furnace, the cold steel is placed, surrounded more or less by grossly powdered charcoal, which deprives of oxygen any little air that may find entrance, while the faggots or pieces are gradually and thus safely, from chemical change, becoming heated up.

“But the steel thus brought to a bright red or even yellow heat, when thrown into the hearth of the furnace to be finally liquified, must still be protected from the evil effects of direct contact with the gases, &c., of the fuel. The means by which this is effected, constitutes the third of the methods, which combined, constitute M. Sudre’s invention.

“While certain bisilicates or silicates, such as those of the refinery hearth for example, exercise a chemical solvent power of amazing energy upon clay compounds, such as fire-brick, &c., it is well known that neutral or basic silicates are almost devoid of any such power. Thus, glass of various constitutions may be kept in a fused state for weeks, and at the high temperature of the glass house furnace, in the Stourbridge (or other like) clay, melting pots, without any serious erosion of the latter taking place.

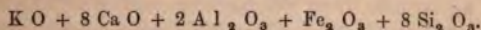
“These basic or neutral silicates (of earthy bases) have no action whatever upon metallic iron or steel, at the fusing temperature of the latter, although they dissolve and take up whatever oxide of iron may be adherent to the surfaces of the metallic masses exposed to them. In brief then, M. Sudre fills, to a *certain point*, the hearth of his furnace with broken wine bottle

glass, or with slag from blast furnaces smelting iron with charcoal fuel, or failing the possession of either of these, with about 60 parts flint or pure siliceous sand, 22 parts of lime, and 12 to 15 parts of alumina (pipe clay), and brings these into perfect fusion.

"Into this bath of fluid glass, the pieces of steel, removed with tongs from the muffle, and already heated to a yellow heat, are plunged upon the hearth of the furnace. The steel being of higher density sinks to the bottom of the glass, by which it is thus completely prevented from all chemical action of the gases of the furnace—while with nothing but a stratum of an inch or two of liquid glass between, it is freely exposed to its heating power. Within the limits of time, during which the steel is here exposed, the silex of the glass will no doubt have no perceptible action upon it. We may mention, however, that iron exposed for *very long* periods, in presence of common window glass (crown glass,) becomes strongly *siliciuretted*. The writer found, some years ago, that pieces broken or dropped off the ends of the iron blow pipes in Mr. Coathupe's works at Bristol, and which had remained for months in the bottom of the glass pots, were converted into globular masses, harder than any file, with a high silvery metallic lustre, and upon analysis proved to contain a definite compound of silicon and iron.

"To each 1,000 pounds of steel he finds it necessary to have about 700 pounds of liquid glass upon the sole of the hearth for complete protection. The glass gets *partially* devitrified, even in a single fusion, but, as in Paris, the price of broken wine bottles is only about twenty shilling per ton, a new supply is not a large item in the expense of the process.

"French bottle glass, like our own, differs much in composition, but all samples approximate to the formula,



Our English bottle glass is frequently made with crude soda, or with Glauber's salts, from the salt cake works, in part at least, and so may not be free from sulphur compounds, which might injuriously act upon the steel. M. Sudre gives his own preference to the French bottle glass, but has also employed with success, the slag from the high furnaces of the Couvin iron works, in

Belgium, the iron of which, produced by charcoal, is justly celebrated. The coal which he actually employed in his experiments, and of which he appears to have burnt in all something like 50 tons, was of very inferior quality, and very ashy.

"He remarks that the glass of the enveloping bath, after the fusion of the steel, had acquired certain bands and stripes of alternate green and blue, which he says had some resemblance to malachite and to ultramarine, but it does not appear to have struck him that this blue banding, (like the intense blue opaque slags, sometimes met with in Staffordshire, and which we have ourselves proved to be artificial ultramarine, accidentally formed in the blast furnace), is no doubt due to the actual presence here of ultramarine; and bearing in mind the nature of Guimet's process for its manufacture, this affords absolute proof of the effective protection which the liquid glass affords to the fluid steel beneath, from the sulphur compounds floating above them.

"The results of M. Sudre's experiments at Montataire, have been to show incontestably, that steel may be thus fused in masses of almost any magnitude, free from deterioration, and that his process is practicable in all respects, capable of being carried on, day by day, in a manufacturing manner, and with an economy far greater than is possible in crucible operations, on equal weights of metal.

"The consumption of coal, (of such quality as he had,) was about 2 pounds for each pound of steel melted, and the total loss of steel in the process varied from about 8 down to less than 5 per cent. Such preliminary trials, however, are no test as to the amount of loss, which must always, in such, be excessive. The process, when systematized, would probably not reach 3 per cent. of loss in actual work.

"The steel employed for these experiments, (probably for economy sake,) consisted, in great part, of old files broken up.

"These apparently, from the large amount of surface rust, and from the teeth being more or less filled with minute particles of brass and copper, or other metals perhaps, do not appear to have given very good results, as to the quality of the steel after fusion into large ingots. Puddled steel, however, both of French make, and from Ynstalyfera, in South Wales, made from anthracite iron, was also fused. And amongst the ingots obtained, pieces sent to the *Musee de l'Artillery* at Paris, were wrought into fine

cutlery tools, and tested in various ways, and found to be of excellent quality.

"M. Sudre's results actually lead to a financial result, of a ton of steel melted at a total cost of about 58 francs; but we do not think it quite fair to fix upon this, so candidly given by him, as at all the minimum to which his process will eventually come.

"He thus sums up the comparative financial statement of his own method, and of the old one of crucible fusion. M. Sudre's process produces an economy of about two-sevenths the fuel, which will, no doubt, hereafter be pushed still further.

"The cost of crucibles is wholly got rid of, which amounts to about 30 francs per ton of steel.

"The cost of keeping in repair the reverberatory furnace is not more than one-third that of the crucible wind furnaces for equal weights fused. Four-fifths of the manual labour employed in the crucible operations are saved—in the case of common sized cast steel ingots, viz., of from 50 to 100 pounds each; but in the case of such gigantic ingots, as those produced by Krupp by his method of multiple pouring from crucibles, it is impossible to say what saving may be effected—probably, more nearly nine-tenths of the whole.

"The outlay in plant for fusing equal weights in equal times by this mode is estimated, by M. Sudre, as two-thirds less than with crucible furnaces.

"In addition to these, as we believe, perfectly well established financial results, we have the simplification and facility of manufacture, and the perfect safety of the workmen insured, as compared with crucible work.

"The form of the ingot moulds, adopted by M. Sudre for his experiments, are shown in elevation and plan in figs. 8, 9, and 10 of our plate (not here given). The latter was intended for gun moulds, but he shows good reasons for abandoning round, i. e., cylindrical ingots for every purpose, and adopting those of the unequal sided octagon instead. These reasons are related to the subsequent process of hammering, and have been anticipated by Nasmyth, Mallet, Clay, and others in this country. The method of pouring or transferring the steel from the hearth of the furnace to the ingot mould, adopted by M. Sudre, consisted in tapping out the

metal, into a crane ladle, lined with more than usually refractory clay, and previously strongly heated.

"In the bottom of the ladle was a hole, stopped by a conical plug or valve of baked clay, on the end of a vertical iron stem, rising above the surface of the liquid steel, by raising which, the jet of metal flowed vertically and directly into the ingot mould.

"This method, called in France, the '*coulée à la quenouille*, i. e., literally *by the distaff*, which the clay plug resembles, has been often employed in our iron foundries, and is that employed by M. Bessemer for pouring the steel made by his patent process.

"M. Sudre, we observe, claims, in his English patent, the exclusive right to the re-melting of steel made by the Bessemer process. Should the Bessemer steel continue to improve in quality, and in certainty of result, as we fully anticipate it will, probably all great masses, such as gun moulds, &c., will be run direct from his converting vessels; and, in so far, M. Sudre's process will be needless, but its value and importance, in re-melting steel, and in many future branches of iron metallurgy, that as yet only dimly show themselves in perspective, will not be superseded.

"Four to five hours, from first charging into the hearth, was found sufficient time to bring into perfect liquidity 600 or 800 kilogrammes of steel. When we recollect that the furnace was fed with *cold air*, that the coal was of bad quality, and that the whole affair was novel, and the brick work of the furnaces and flues, in all the latter experiments, soaked in wet, from the overflow of the Seine river in flood, we see that this short time can still be greatly curtailed hereafter. The employment of *hot blast* is provided for by M. Sudre in his specification, and its use will, no doubt, greatly advance all the objects of his method. We believe he might also greatly improve his method, or, at least, still further exalt the temperature, and reduce the time, of action of his furnace, by employing for fuel, *at the last stage* of the process, pure anthracite coal of the hardest quality, such as that of Kilkenny, already brought into ignition in a separate fire place, and devising means by which it should be fed into the grate of the reverberatory furnace, in measured bulks, without ever opening any aperture to the external air. For, although with the fan blast, the rush of flame is *outwards* and cold air is not introduced, the regimen of the flame at its point of maximum

intensity is thus, for the moment of feeding with fresh fuel, constantly disturbed and the heat lowered. One immense advantage of such anthracite as we above refer to, is also that it produces literally almost no elinker to choke the bars—and this is the point in M. Sudre's invention which in practice we are disposed to think will be the most troublesome, to feel one's way to perfection with.

"As this method becomes employed, it must give rise to a demand for fire bricks and moulded blocks, of various large sizes and forms, for building these furnaces, of a far higher quality, and much more refractory, than anything at present in the English fire brick market. In these we have much to learn from Germany, where crucibles (*tiegel*), bricks, and all forms of fire blocks, &c., are made of a quality and infusibility that we have not yet attained to. M. Sudre well remarks, that the *larger* the blocks of which his furnaces shall be built, the longer and better they will stand the severe action of the fuel, &c.; and he advises coal to be employed, that shall not contain more than 3. per cent. of ashes.

"The statements made by M. Sudre in this remarkable memoir are fully borne out by the report of the three Commissioners of the Emperor, who were present at several of the experiments. They state that it has been proved satisfactorily, that thus a mass of upwards of two tons of steel may be fused, without any injury to its qualities, and with remarkable economy and facility. Two tons is yet a long way behind Krupp's—20 tons ingot; but there is no reason why 20 or 50 tons should not be thus melted, in one or more furnaces.

"This invention must promote powerfully the much-needed abolition of wrought iron in paddle shafts, cranks, screw shafts, &c. Why should not all our propeller screws, too, be now cast in steel at once, in place of making them of gun metal, at an enormous cost, and to the destruction by corrosion, of their own shaft necks, and of all the iron of the ship around them.

"The day, too, of wrought iron artillery ought soon to end; small guns, all up probably to 32 pounders, may be cast, and forged, and finished solid; but although M. Sudre's methods give the means of casting, and afterwards forging in *one mass*, guns enormously larger than even Krupp has done, it will be

most unwise to turn back, from that ringed structure with initial tension which alone can give the maximum strength from a given weight of metal.

"What these improvements in steel point towards, as respects the heaviest classes of artillery, is this, that *welding*, as well as wrought iron, with which it is inseparably connected, should be abandoned. That every separate piece and ring of a gun, whether Armstrong or any other, *should be produced from the liquid state in a single united mass*, and that thus, while on the one hand the uncertainty of welded unions is got rid of; we substitute in the change, for a material of about 30 tons breaking weight, one of from 70 to 90 tons per square inch."

Much discussion exists upon the molecular constitution of steel, its true association with carbon being to a certain extent still misunderstood. Many experiments have been instituted with a view to settle this question, but the results obtained have almost been as inexplicable as the original subject itself. From the '*Chemical News*' we extract a number of experiments instituted by M. Caron:—

"Karsten observed that by the action of acids upon soft steel, a graphitic substance is obtained as a residue, which is not obtained by the action of acids upon hardened steel. This substance he represented to be a definite carburate of iron FeC^6 . Berthier also stated that cast steel contains another carburet, CFe .

"M. Caron* infers, from the results of numerous analyses, that these carburets are probably mere variable mixtures of carbon and iron, in which the iron is protected mechanically by the carbon from the solvent action of the acid.

"He has experimented upon steel in three different conditions—

- "1. Steel as it comes from the cementation chambers.
- "2. The same steel hammered for a long time.
- "3. The same steel hardened.

"By the action of hydrochloric acid on these three kinds of steel, the quantities of graphitic residue obtained are very different, being for 100 parts as follow:—

* *Comptes-Rendus*, lvi., 43.

	Graphitic residue.	Carbon.	Iron.	Silicium.
Ordinary steel	1·624=0·825	0·557	0·242	
Hammered steel	1·243=0·560	0·445	0·238	
Tempered steel	0·240=trace.	trace.	0·240	

"These results show that the effect produced by tempering is to some extent produced by hammering, and the quality of the steel appears to improve in proportion as the carbon is intimately combined with the iron.

"In the same manner forging, which improves the quality of steel, also reduces the quantity of carbon that is separated by solution in acids. Rolled steel gives more graphite than hammered steel. The influence of heat in this respect is the reverse of that produced by hammering and tempering, and re-heated steel does not recover its primitive quality, or its chemical properties, as regards acids, until after it has been hammered or tempered.

"White pig iron presents the same variation in the quantity of carbon that it contains in a free state, and the duration of the annealing. However long this may last, there is still some carbon remains uncombined.†

"In the tempering of steel, the rapid cooling has a compressing influence upon the metal, almost instantaneous, and presenting the closest analogy with the blow of a hammer.

"A bar of steel rapidly heated to the temperature requisite for tempering, and immediately plunged into cold water, underwent the following alterations of bulk:—

	Before Tempering.	Red hot.	Tempered.
Dimensions in centimetres	20·00	20·32	19·95
	1·00	1·03	1·01
	1·00	1·03	1·01
Volume ditto	20·00	21·557	20·351

"The effect produced by the tempering consists in a rapid approximation of the particles acting in every direction. It is this concussion which M. Caron regards as producing the combination of the iron and carbon. The increase of temperature has the effect of dilating the metal and giving to the molecules a mobility necessary to enable them to unite; the sudden cooling bringing them rapidly together, causes combination.

"A bar of iron heated to bright redness was briskly ham-

† *Comptes-Rendus*, lvi., 211.

mered on an anvil covered with finely-powdered carbon; when it had cooled to a dull red heat, it was suddenly plunged into cold water. Some parts of the bar were then found to have been converted into steel at the surface, and resisted the file. The same iron heated to redness, and cooled in the midst of charcoal without being hammered, did not present any trace of being converted into steel when tempered in the same manner.

"Hammering does not effect so complete a combination as tempering, because it causes the concussion of the particles only in one direction, while the sudden cooling in water causes their concussion in every direction simultaneously. Moreover, the temperature of the metal after hammering tends to destroy the combination that has been effected by it. On the contrary, the metal being quite cold after the concussion produced by plunging it into water, no further reaction is possible, except by heating the metal again.

"Reaumur* and Rinman† state that the volume of tempered steel is 1·48th greater than that of soft steel. Karsten,‡ on the contrary, says that it is not quite certain that all steel expands by tempering, and becomes of less density. In M. Caron's experiments on this subject, he heated the steel in earthen tubes filled with hydrogen. A bar of hammered steel, 1 centimetre square and 20 centimetres long, was tempered, and found to be reduced in length to the extent of half a millimetre; the other dimensions were increased 0·06 mm.; the density was rather less than before, 7·796 in place of 7·817. These differences being small, the experiment was repeated several times with the following results:—

	Before tempering.	10 times.	After tempering	
			20 times.	30 times.
Dimensions in centimetres	20·00	19·50	18·64	17·97
	·94	·96	·97	1·00
	·93	·96	·97	1·00

"Hence it appears that the reduction in the length of bar after thirty temperings was nearly one-tenth. The diminution in length was not due to oxidation, and the sharpness of its edges was retained almost entirely. The bar was then cleaned, and

* "L'Art de Convertir le Fer Forgé en Acier," p. 338.

† Rinman, I., 220 to 223.

‡ Karsten, III., 380.

the density found to be 7.743; consequently the volume had increased.

"Similar experiments with a great number of bars of steel gave like results, and M. Caron concludes, that in tempering, steel bars are reduced in length, while the width and thickness augment in the same proportion as the density is reduced.

"The opinion expressed by Karsten, and the differences observed in steel of different manufacture, induced M. Caron to continue his examination to drawn and sheet steel, with the following results:—

	Dimensions before tempering.	Dimensions after tempering.
Round drawn bar steel	20.05 1.16	19.98 1.16
Rolled steel (German plates)	20.00 1.51 3.70	20.45 1.51 3.70

"These results, and those already given, show that in tempering—

"1. Hammered steel bars are reduced in length.

"2. Round bars partly hammered and partly drawn are scarcely altered in length.

"3. Plate-steel increases both in length and width.

"4. In all cases the density diminishes—a result which agrees with M. Regnault's observation, that soft steel is denser than tempered steel.

"It appears, therefore, that a bar of steel may, in tempering, change its dimensions in a different manner, according to the mode of its manufacture. This accounts for the fact that slender articles, such as files, become twisted; this would naturally be the result if, in forging, one side were more hammered than the other. At the moment of immersion in water, the side that has been most hammered diminishes in length more than the other, so giving rise to the defect.

"The effect of the sudden cooling of steel in tempering, may be compared in other respects to the effect produced by the blow of a hammer. Thus, the more sudden it is, the more considerable is the corresponding force exercised, and the greater will be the hardness. This may be inferred from the following table,

representing the time of cooling of a bar of steel, and the corresponding degrees of temper produced in the metal:—

	Water.	Water.	Water with 10 per cent. dextrine.	Alcohol
Original temp. of the liquid	10°	50°	10°	10°
Final temp. of the liquid	22°	61°	23°	30.5°
Time of cooling	4.7	11.3	13.2	21.7
Degree of temper.	good.	slight.	very slight.	none.
Shortening of the bar	1.28	1.147	1.172	{ insen- sible.

“The result of a great many experiments with various liquids—mercury, saline or acidulated solutions, water covered with oil, or containing in solution mucilaginous or syrupy substances, oil, &c.—appeared to indicate that the hardness and other characters produced by tempering are inversely proportionate to the square of the time of cooling.

“M. Deville* regards these results as accordant with the results of his observations on the remarkable physical and chemical properties communicated to substances by rapid cooling, or, in other words, the excessive proportion of latent heat, or heat of constitution, they retain when suddenly cooled.

“Those observations showed that substances might, in this respect, be divided into two very distinct classes.

“One class comprises sulphur, selenium, silicium—or rather its compounds, silica and silicates—and the experiments of Jacquelin, Lavoisier, and Silliman justify the addition of carbon to these. The other class includes lead, tin, bismuth, and probably metals generally. The substances of the former class are ‘superfusable,’ and capable of being tempered, and acquiring the vitreous or amorphous condition. The substances belonging to the second class present the same molecular condition after cooling either rapidly or slowly, their density remaining constant.

“M. Deville considers that the results obtained by M. Caron may be explained by regarding iron and carbon as belonging respectively to these two different classes. Those results and Karsten’s show that iron and carbon combine at a high temperature; that if the compound is allowed to cool slowly, the constituents crystallize separately, the mass acquires a maximum

* *Comptes-Rendus*, vi., 325.

density, and acids effect its separation into iron and a graphitic substance. On the contrary, when the cooling is sudden, the carbon remains in a state of superfusion, and communicates the property to the compound containing it in the same manner that silica communicates this property to alkalies and metallic oxides.

"When the proportion of carbon is larger than in steel, rapid cooling gives white pig iron, and slow cooling grey pig iron.

"From this point of view, steel may be compared to glass, which becomes divitrified when it is heated, or to sulphur, which becomes octahedral sulphur when heated to near 100° C. It is, indeed, worth inquiry whether in the tempering of steel, the effect produced is not absolutely similar to that observed in tempering sulphur; that is to say, the production of two distinct layers, one superficial and very thin, the other internal, and corresponding respectively to insoluble and soft sulphur.

"In any case, the sudden approximation of the molecules determined by tempering, and compared by M. Caron to the effect of hammering, maintains permanently a greater distance between the molecules than their gradual approximation by slow cooling.

"As regards heat of constitution, there is in such a case a retention of a certain quantity of heat, which is, on the contrary, disengaged during slow cooling. This is the condition which M. Deville terms superfusion.

"In the case of the different kinds of allotropic sulphur, it has been possible to some extent to measure the quantity of heat evolved during the transformation of soft sulphur and insoluble sulphur into octahedral sulphur. In the case of steel, the density and calorific capacity afford only indirect evidence of the existence of similar conditions.

"M. Deville considers that not only carbon is capable of converting iron into white pig iron or steel, but that, in accordance with the views above expressed, any of the electro-negative elements placed in the same condition as carbon would have that effect. Nitrogen he considers to be especially suited for this purpose.

"A continuation of M. Caron's researches on this subject relates to the function performed by manganese in the production of steel. Regarding it as a fact that all good steel is obtained from *spathic* or *hematite* ores highly impregnated with man-

ganese, and assuming that the presence of this metal is almost essential to the production of steel, he has endeavoured to ascertain the nature of its influence. He states that, by means of a suitable addition of metallic manganese, pig iron may be deprived of the sulphur and silicium it contains, but that no influence is exercised in the separation of phosphorus.

"The pig iron with which he experimented is described as of very good quality, containing only traces of silicium, and it was melted by means of wood charcoal as free as possible from phosphorus, sulphur, and silicium.

"One portion of this pig iron was melted with a known quantity of iron phosphide; another portion, with iron sulphide; and a third, with iron silicide. The three kinds of iron thus obtained were the subject of the experiments.

"Two equal quantities of the phosphuretted iron were melted in crucibles; in the one instance without any addition, in the other instance with 6 per cent. of metallic manganese. The manganese used gave on analysis:—

Iron	1.0	} 100
Carbon	5.5	
Silicium	0.5	
Manganese	93.0	

"The metal was kept in fusion for one hour, and then poured out. During the operation the metal was slightly decarbonized by the oxidizing action of atmospheric air. Analysis of these two portions of iron gave the following per-centage results:—

	Phosphorus.	Manganese.
Phosphuretted iron	0.83	
No. 1. Phosphuretted iron melted alone	0.82	
No. 2. Phosphuretted iron melted with 6 per cent. manganese	0.80	4.58
No. 1. Melted again without addition	0.79	
No. 2. Melted again without addition	0.78	3.74
No. 1. Melted a third time without addition	0.78	
No. 2. Melted a third time without addition	0.76	1.62
Phosphuretted iron melted with 10 per cent. iron oxide	0.76	
Phosphuretted iron melted with 10 per cent. iron oxide and 6 per cent. manganese	0.74	1.57

"These results appear to indicate that, in refining phosphur-

etted pig iron, manganese does not effect the separation of phosphorus.

	Sulphur.	Manganese
Sulphuretted iron	1.15	
No. 1. Sulphuretted iron melted alone	1.14	
No. 2. Sulphuretted iron melted with 6 per cent. manganese	1.15	3.92
No. 1. Melted again without addition	1.05	
No. 2. Melted again without addition	0.10	2.81
No. 1. Melted a third time „ „	0.96	
No. 2. Melted a third time „ „	0.08	1.73
Sulphuretted iron melted with 10 per cent. iron oxide	1.08	
Sulphuretted iron melted with 10 per cent. iron oxide and 6 per cent. manganese	0.07	1.22

“These results show that, by simple fusion with access of air, manganese effects the separation of 7-10ths of the sulphur in the pig iron. Repeated melting, without further addition of manganese, does not produce any considerable effect, and it appears that the proportion of manganese should be large, for by remelting the same metal with a fresh quantity of manganese the sulphur may be almost entirely separated.

	Silicium.	Manganese.
Silicetted iron	0.99	
No. 1. Silicetted iron melted alone	0.88	
No. 2. Silicetted iron melted with 6 per cent. manganese	1.30	4.77
No. 1. Melted again without addition	0.80	
No. 2. Melted again without addition	1.66	2.98
A. Silicetted iron melted with 10 per cent. iron oxide	0.61	
B. Silicetted iron melted with 10 per cent. iron oxide and 6 per cent. manganese	0.37	2.52
A. Melted again with 10 per cent. iron oxide	0.52	
B. Melted again with 10 per cent. iron oxide	0.18	1.10

“The manganese used in these experiments contained silicium, and in this way, as well as by reducing the silica of the crucible, added to the amount of silicium in the iron. But this is not the case when the iron is decarbonized by the addition of iron oxide.

“It may be inferred from these results, therefore, that manganese determines the separation of a large portion of the silicium in pig iron.

“These results agree with practical experience. The ores above

mentioned, that yield the better kinds of steel, often contain sulphur, but never contain phosphorus; and it is a noteworthy fact that, although those ores contain copper pyrites, the pig iron they yield does not contain sulphur.

"Although manganese does not determine the conversion of iron into steel, as Karsten has well shown, it is nevertheless certain that—besides rendering steel capable of being welded—it has an influence in improving the quality of steel. M. Caron considers that this influence may be explained by the aid of facts which he has formerly made known. When a sufficient quantity of manganese is added to grey pig iron, the carbon of which is to a great extent in a free state, white pig iron is obtained, in which the carbon is almost entirely in a state of combination. The effect is the same with steel; a very small addition of manganese is sufficient to retain the carbon in a state of combination, and, in consequence, to confer on the metal the characters peculiar to good steel. However, the amount of manganese in steel must not exceed 5-1000ths; more than that renders steel hard and brittle, the surface of fracture becomes crystalline, and the metal is deficient in tenacity.

"It is a common practice in refining iron to mix ordinary pig iron with manganiferous pig iron, and the above results show that the beneficial effect of this practice is greater according to the amount of manganese present. It appears, therefore, to be a point of practical interest to reduce manganiferous ores in such a manner as to obtain the largest possible amount of manganese in the pig iron. The spathic ore of the Siegen district contains from 15 to 20 parts manganese for 100 of iron; but the pig iron made there does not contain more than 6 or 7 per cent. of manganese. M. Caron considers that if this amount could be increased to 10 per cent. the commercial value of the pig iron would be increased."

The vast superiority of steel, as a material for resisting extreme strains, leads us to expect that it will eventually occupy in the constructive arts the position which wrought iron now occupies as contrasted with the past use of cast iron. Steel produced by the Bessemer process seems to be of excellent quality, and of superior iron. The only problem remaining to be solved is the

"These results of this steel in large quantities at a moderate

cost. When such is done, we shall find that it will be to the interest of engineers, in every sense of the word, to adopt such a safe and most trustworthy material. We may then expect to see steel cylinders, steel boilers, steel ships, and armour plates, and in short, everything at present of iron will be made of steel at half the expenditure of material, and with increased durability. Before this, however, can be done, and in addition to the production of such quantities of steel at a cheap rate engineers will require to be provided with data indicating the behaviour of steel under different circumstances, as in ships, boilers, and other structures. Until such are supplied, engineers will be slow and cautious in their adoption of steel in many instances where it might yield good results. We would therefore suggest to those interested in the general introduction of steel as a substitute for wrought iron, that they should conduct such experiments as would enable them at once to supply the necessary data to engineers, and thus bring forcibly before their attention the demonstrated advantage to be derived by the adoption of such a material.

In all the varied applications of the three combinations of iron with carbon, considerable difference of opinion exists as to how far we should trust such materials under strain or load. Of course, this materially depends on the quality of the sample in use. The breaking load of any iron can be ascertained by the simple experiment of testing a bar one inch square till it breaks. This has been done with almost every quality of iron, and will be found recorded in almost every engineer's Pocket Book; it is, however, usual in casting large work, to cast at the same "pouring," a test bar, so as to ascertain the exact breaking weight the particular iron or mixture will resist. Once this is known the question presents itself, What is the *Factor of safety* at which it would be prudent to load such a casting? This is the question to which scarcely two engineers will be found to give the same answer. Professor Rankine, in his "Civil Engineering," gives the following as examples of actual practice:—

	Ult. Strength ÷ Proof Strength.	Ult. Strength ÷ Working Load.	Proof Strength ÷ Working Load.
Strongest Steel	1·5		
Ordinary Steel and Wrought Iron, Steady load	2·0	3·0	1·5
" " Moving load	2·0	4 to 6	2 to 3
Wrought Iron riveted structures	3·0	6·0	2·0
Cast Iron Steady load	2 to 3	3 to 4	about 1·5
" " Moving load	3·0	6 to 8	2 to 2·66

The above three columns represent the ratio in which the *ultimate load should exceed the proof load*, the *ultimate load the working load*, and the *proof load the working load*. It is an established maxim to err on the safe side, but it is unquestionably erring at best when material is needlessly employed to secure an over safety in any structure; it is, therefore, important that such a subject as this should be set at rest. For its further illustration we quote the following excellent paper on the Relations between the Safe Load and the Strength of Iron, by Zerah Colburn, Esq., C.E., read before the Society of Engineers:—

"A great number of experiments have been made by many experimenters, to ascertain the ultimate resistance of iron to tension and compression, and its strength has thus been determined with perhaps as much precision as is possible in the case of a material presenting almost constant variations of quality. Every engineer is now aware that, as an average result, the tensile strength of cast iron may be taken as about 8 tons per square inch, and its crushing strength at 48 tons. Wrought iron of fair quality will bear from 26 tons per square inch in tension, while its crushing strength is variously stated at from 12 or 15 tons per square inch up to 28½ tons, the last named being given by Mr. Mallet as the result of experiments upon large hammered bars, which bore but from 23 tons to 24 tons in tension.

"When, however, we come to the question of safe-working strength, much difference of opinion exists among engineers, the permanent supporting power of iron being variously estimated at 4-10ths down to 1-10th of its breaking strength. Thus when, some fifteen years ago, a Royal commission sat to inquire into the

application of iron to railway structures, the late Mr. Glynn, in his evidence, recommended that a cast-iron bridge should never be loaded beyond one-tenth of its ultimate strength. The late Mr. Stephenson, with several other engineers, thought a ratio of one-sixth sufficient, while the late Mr. Brunel was satisfied with a ratio of from two-fifths to one-third; or, in other words, if a girder would just bear 100 tons of distributed load, he would put from 33 tons to 40 tons upon it, where Mr. Stephenson would allow not more than 17 tons, and Mr. Glynn only 10 tons.

"Were we now to have another commission intrusted with the same inquiry, it is not unlikely that as great a difference of opinion would be found still existing. For there is no acknowledged natural principle upon which the safe load of iron has yet been determined, and in the absence or oversight of such a principle each engineer must be governed by his own judgment of what is safe and prudent. It is true that the authority of the Board of Trade has been so far exercised in this matter as to have limited engineers, in the design of wrought iron railway bridges, to maximum tensile strains of 5 tons per square inch; and although it is commonly believed that with wrought iron a compressive strain of from 4 tons to $4\frac{1}{2}$ tons corresponds to a tensile strain of 5 tons, the Board of Trade impose the same limit of strain for both the top and bottom chords of a wrought iron girder. The limit of 5 tons per square inch, it is hardly necessary to say, is an entirely arbitrary one, nor is it modified according to the quality of the iron and workmanship in a structure. Thus, in girder bridges, plate iron is used, of which the breaking strength is occasionally not more than 18 tons per square inch. In punching the rivet holes, however, and irrespective of the loss of the metal actually punched out, the solid iron remaining between the holes is injured, so much so that, in a series of experiments made many years ago by Mr. Fairbairn, the mean tensile strength of seven specimens was reduced from 52,486 lb. per square inch before punching to 41,590 lb. per. square inch of solid iron left between the holes after punching—more than 20 per cent. of the strength of the iron being destroyed by punching, a loss distinct from that of the metal actually punched out. Drilled rivet holes, it is satisfactory to know, are now being adopted in the best *class of bridge work*; but in bridges already erected and contain-

ing plates occasionally no stronger than 18 tons per square inch before punching, the loss of strength ascertained by Mr. Fairbairn would diminish this to about $14\frac{1}{2}$ tons for the net section of metal between the rivet holes. On the other hand, the best suspension-bridge links have a strength of from 26 tons to 28 tons per square inch of section, and yet the Board of Trade inspecting officers would not probably depart from the arbitrary limit of a maximum strain of 5 tons in either case. As far, therefore, as is necessary to meet the requirements of the authorities, good iron and sound workmanship go for little or nothing: and not only does this remark apply to the inference of the Board of Trade, but in the case of Chelsea suspension-bridge, the chains of which are believed to have a tensile strength of upwards of 25 tons per square inch, two of the leading members of our profession have declared that structure to be unsafe until it shall have been so strengthened that the greatest load which the heaviest traffic is likely to bring upon it shall not exceed 5 tons per square inch of the sectional area of the chains. The highest authorities, we are justified in supposing, would, at the same time, be satisfied with the same maximum strain in the chords of a plate girder bridge, even if the actual breaking strength of the solid iron between the rivet holes did not, as we have reason to believe it often does not, exceed 15 tons, or three-fifths that of the links of Chelsea Bridge.

“While some of the conditions of elastic action are now under consideration, it appears desirable to define, as nearly as may be, what elasticity really is. We are all familiar enough with its manifestations, as in a watch spring, an air cushion, or a bit of india-rubber, but we seldom inquire to what condition of matter these manifestations are to be attributed. When, however, we regard matter of any kind as a collection of distinct molecules or atoms, between which the force of attraction is always predominant in solids, and the force of repulsion in gases, we have no difficulty in perceiving that any alteration in the amount of either of these forces, acting within a body, must produce a corresponding change in the distance between its atoms, and in this very change of distance we have the whole phenomenon of elasticity. Elasticity is not a force, but the result of the antagonism of two *opposite forces*: an antagonism in which either force continues

to act through a certain range or distance—a range differing greatly in different materials—before being completely overcome by the opposite force. Under the influence only of attraction the particles of all matter would cohere, and without repulsion there could be only solid bodies in nature, for the existence of liquids and gases would then be impossible. The repulsive force appears to be the force of heat, to which physical repulsion may be generally traced. Under the influence of heat alone, and without attraction, there could be neither cohesion nor liquidity, and all substances could exist only in the gaseous state. We shall soon be able to trace the bearing which these distinctions have upon the elasticity of iron. At present we have only to bear in mind that there is reasonable physical evidence to show that the atoms of matter, so far as we can comprehend their existence, are never in actual contact with each other, even in solid bodies. Iron, as we know, is a comparatively porous material, since air and water may be readily forced through it under moderate pressures. Mercury, it is well known, will rapidly insinuate itself between the pores of an apparently solid body, for gold immersed in mercury will acquire the condition of an amalgam, and will crumble to powder. We know, furthermore, that the particles of most, if not all, solid bodies may be so far separated by heat as to convert them into liquids, and it is quite reasonable to suppose that, with an additional degree of heat, or repulsive force, all these liquified solids might, like mercury, and even melted gold, be converted into vapours. Now, any force applied after the manner of tension in a bar of iron, thus tending to separate the particles, in opposition to their cohesion or force of mutual attraction, may be considered to act in the same manner as the repulsive force of heat. The point at which rupture will take place will evidently be where the particles are so far separated that the cohesive force is less than the tensile strain, but there is good ground for supposing that, even after rupture, the atoms of the iron would again cohere could they be again brought to within their original distance from each other. This, of course, would be impossible if we attempted merely to place the two fractured surfaces in contact. In the case, however, of two clean surfaces of lead, we may readily bring them so closely together as to restore cohesion, and, in the same way iron journals

running in steel bearings occasionally become welded to them when the pressure is too great for ordinary work. In thus bringing two bodies within the range of cohesive force, we must remember that it is the ultimate atoms which cohere, and that the finest perceptible particle of matter may really consist of myriads of almost infinitely smaller atoms. In all welding we first employ a degree of heat sufficient to overcome so much of the cohesive force between the atoms of the iron as to allow of sufficient motion among themselves to bring all, or most of the atoms forming one surface, within cohesive range of those forming the opposite surface. Two cast-iron surfaces are readily welded together by running melted iron between them. Without heat the two surfaces, however well-finished, would touch only at a great number of separate points, although there would be considerable cohesion even then, as every one knows who has brought two carefully scraped surfaces of iron, or two sheets of plate-glass together; and although a part of the apparent cohesion is due to the pressure of the atmosphere, there would really be some cohesion in a vacuum. It is only from the fact that the atoms of matter will always cohere when once brought sufficiently near together, that we are enabled to make bricks and all articles of earthenware. Soluble bodies, like clay or salt, cohere after solution and evaporation, simply because their atoms, having been first separated by the liquid solvent, are again left within cohesive range on the evaporation of that solvent. Bricks, but for the waste of fuel in burning them, might be made from the most dilute solution of clay, and the final baking is only necessary in order to so completely expel the moisture as to bring the clay atoms within the range of cohesion, but their own character is in no respect altered. Iron, were it possible to dissolve it without combining it with nitrogen, oxygen, sulphur, or other matters, would again return to its ordinary granular state, and would recover its cohesion, on the evaporation of the solvent. Great pressure, too, will effect cohesion in the case of substances naturally having none at all. Thus, in experiments made with the ballistic pendulum to ascertain the velocity of cannon shot, the sand packing against which the shot is fired is often converted into sandstone of considerable strength.

"From the illustrations given, the elasticity of solids appears

to be no more than the range or play of the attractive and repulsive forces of matter, as variably exerted, but within the limits of rupture or crushing. Thus elasticity is the same in kind whether the repulsive or separating force be externally applied, or whether it be that of heat acting between the molecules of the body. If a bar of good wrought iron be stretched to the 1-1000th part of its length, corresponding, say, to a strain of 10 tons per square inch, its elasticity will be fully excited or nearly so, and it will not support a much greater strain without taking a permanent set. It is true that, if the same bar of iron, when not under strain, be heated to from 150 to 200 deg. above its normal temperature, it will also elongate by 1-1000th part of its length, and that without injury. But if this elongation takes place under a compressive strain, or, if the iron, first raised in temperature by 200 deg. and thereby elongated, be attached to two fixed points, and thus, while cooling, be made to contract under strain, it will be found that an elongation of not far from 1-1000th of the original length of the bar is the most that can be borne without injury, even when that elongation is due to heat alone. But if the iron be first heated sufficiently to soften it, as railway tyres and gun hoops are heated, the particles will be re-arranged, and, within certain limits, without injury; but after the metal has once cooled below the temperature at which the particles have the mobility necessary for this rearrangement, any further contraction around an unyielding object will be attended with permanent, and, there is reason to believe, injurious strain. Even in setting railway tyres, it is believed to be best to put them on cold, and under graduated pressure; and in the case of gun hoops, Captain Blakely and Mr. Mallet, who appear to be entitled to the credit of the modern system of the ringed construction of artillery, have always insisted upon the importance of a definite degree of shrinkage of each ring, so that the consequent strain shall not exceed the elastic limit of the material. Sir William Armstrong has stated that he does not consider any especial accuracy essential in the distribution of the strains imparted by shrinking his gun hoops upon each other; but it may be questioned how far the failures of so many of the Armstrong guns have been due to neglect in this respect.

"It would be interesting to know the precise manner in which

a separating strain acts upon the molecules of iron, or rather to know the successive positions of the atoms during the application of the strain. We are, however, without any positive knowledge of the positions which the atoms assume in solidification and under subsequent forging; but the multifarious forms in which all atoms visibly crystallize serve to show us that they cannot all be at equal distances from each other throughout the whole body. If they were, the arrangement would be that of cannon balls in a triangular pyramidal pile. Could we visibly represent the atoms as occupying the angles of an infinite number of equilateral triangles, we should understand that a linear strain acting to separate any two of the atoms would, at the same time, draw a third atom, if not a number of atoms partly between them. And when, from this intrusion, the repulsive force, or heat, always enveloping the intruding atom, had once overpowered the attractive or cohesive force existing between the two atoms thus strained apart, these would, in turn, cohere anew to the atom which had been drawn in between them, and thus we should have a permanent rearrangement of the atoms, or, in other words, a permanent set, with permanent elongation in one direction, and permanent contraction in a plane at right angles thereto. That the atoms are thus drawn into parallel rows of straight lines, in many kinds of iron at least, seems evident from the appearance of fracture, which presents stringy collections of particles forming what is commonly called fibre, although there is great reason for doubting that anything like fibre existed in the iron before it was broken. Mr. Kirkaldy's recent extensive experiments appear to show, as many others have shown, that iron may be made to break short or to break with an appearance of fibre, just according as it is broken with a sudden blow or a gradual pull. Something like fibre may be imparted, on a coarse scale, by repeated rolling or in wire-drawing; but it is more probable that masses of atoms are thus drawn into strings than that any fibre is really imparted to the atomic arrangement itself.

"It is commonly held that, within certain limits of strain, iron is perfectly elastic. No matter how often it may be stretched or deflected, up to a certain point the general belief is that it will come back to its original form every time the load is taken off. There are high authorities, however, who maintain that iron takes a per-

manent set under even very moderate strains. If we are to understand that the set is exceedingly small, this may be true. The late Mr. Hodgkinson, for example, remarked, on the 381st page of his 'Experimental Researches,' that two cast iron beams took each a permanent set with weights respectively equal to 1-57th and 1-80th of the breaking weight. In a discussion at the Institution of Civil Engineers, a Mr. Dines mentioned that he had tested upwards of 8,000 cast iron girders for the late Thomas Cubitt, and that he found it hardly possible to apply a weight so small as not to produce some permanent set, 1-20th of the breaking weight producing a perceptible set. In the experiments of the Iron Commission at Portsmouth a bar of annealed wrought iron 50 ft. long was said to have taken a perceptible set with a weight of less than $1\frac{1}{4}$ ton per square inch. After this weight had been doubled, however, the set was still only perceptible; and notwithstanding that the elasticity of annealed iron is known to be inferior to that of unannealed bars, the whole set of the 50 ft. bar was but the 1-250th part of one inch, after a strain of $8\frac{1}{3}$ tons per square inch had been borne; and the set was but the 1-20th of an inch in 50 ft. after a strain of 11.9 tons per square inch. Mr. Edwin Clark has experimented on a wrought iron bar 10 ft. long and 1 in. square. Under a strain of 3 tons per square inch he gives a permanent set of nearly the 1-4000th part of an inch in 10 ft. With 8 tons the permanent set is given as about the 1-1280th of an inch in 10 ft., and it was not until a strain of 13 tons per square inch had been applied that a set of 1-32d of an inch in 10 ft. became apparent. With such exceedingly minute measurements, we may, perhaps, doubt if there was really any permanent set at all, with strains under 9 or 10 tons per square inch. An increase of temperature in the bar of perhaps a single degree, while the measurements were being made, would more than account for some of the reported sets, even under considerable strains. Thus Mr. Edwin Clark gives the permanent set of his bar, after a strain of 8 tons per square inch, as the 1-153,846th part of its length, and this is almost exactly what the extension of the bar would have been had its temperature been raised but a single degree between the observations. Iron is heated in the very act of straining it, and a sudden breaking strain will generally leave the broken ends too hot to be handled.

Such a slight apparent extension might also have occurred while the shackles by which the bar was strained were coming to their bearings. But even if such a microscopic permanent set really existed, it is one of which no engineer would take the slightest serious notice as affecting the strength of the bar in which it was observed. With the means of measurement commonly employed by engineers ordinary wrought iron is seldom permanently stretched until after it has borne strains of upwards of 8 tons per square inch. In seven experiments by Professor Barlow, on wrought iron bars 10 ft. long, two of them retained their full elasticity under a strain of 11 tons per square inch, three bars bore 10 tons without injury, while one bore $9\frac{1}{2}$ tons, and another, made from old furnace bars, did not retain its elasticity beyond a strain of $8\frac{1}{4}$ tons per square inch. All the links for the Pesth Suspension-bridge, upwards of 5,000 in number, and 12 ft. long from centre to centre, were tested without permanent set up to 9 tons per square inch, and those of Chelsea Suspension-bridge were tested without permanent elongation up to $13\frac{1}{2}$ tons per square inch. Mr. Edwin Clark, from the results of his experiments, considers that the limit of elasticity of wrought iron is 12 tons per square inch, and this appears to have been adopted by him both for bars having a breaking weight of 24 tons and for plates having a breaking weight of 20 tons. Every chain cable purchased by the Admiralty is tested up to 11.46 tons per square inch of the metal in each side of the link, the standard test being 630 lb. for each circular $\frac{1}{8}$ in. of the diameter of the iron of which the cable is made, one-half of this strain coming upon each side of the link. The iron of which the cables are made does not, as a rule, take any permanent set when strained to this amount, or to say $11\frac{1}{2}$ tons per square inch. Mr. Howard has stated that the best iron begins to stretch permanently under about 10 tons per square inch in 10 ft. lengths, although he occasionally tests up to 15 tons or 16 tons per square inch; the breaking weight being from 26 tons to 28 tons. Mr. Mallet, about four years ago, presented to the Institution of Civil Engineers the results of a valuable series of experiments on wrought iron and puddled steel, from which it appeared that the elastic limit and the breaking strain under tension were, in the case of certain samples, as follow:—

	Elastic limit. Tons.	Breaking weight. Tons.
Hammered slab or bar, 12in. by 4in.	14·312	24·062
Hammered bar	15·219	22·969
Rolled slab or bar 12in. by 4in.	10·937	22·969
Rolled bar	10·937	22·969
Faggoted forged slab, 4ft. by 4ft. by 1ft.	8·750	18·594
Original faggot bars, Horsfall gun	12·031	21·875
Longitudinal cut, forged mass	9·844	19·688
" " " " " "	10·937	17·900
Circumferential " " " " " "	6·562	16·406
" " " " " "	5·470	16·716
Transverse " " " " " "	3·281	6·562
Charcoal rolled bar from borings from the Hors- fall gun	5·470	22·321

"Sir Marc Isambard Brunel made a number of experiments on Yorkshire iron, hammered to small dimensions, or from $\frac{3}{8}$ in. to $\frac{1}{2}$ in. square. A very high elastic limit was obtained, as follows:—

"Mean of ten bars began to stretch with 22·2 tons per square inch, the mean breaking weight being 30·4 tons per square inch. With ten other bars the mean strain at which they began to stretch was 24·4 tons, the breaking strength being 32·3 tons per square inch. It is to be borne in mind, however, that these bars were reduced by the hammer only at the centre of their length, and that, therefore, the stretching could be observed upon but a very small part of their length. Mr. John A. Roebling, the engineer of the Niagara Suspension-bridge, has made experiments upon bars similarly drawn down to $\frac{3}{4}$ in. square at the centre, the breaking weight being 33 tons per square inch; these bars bore a strain of $20\frac{1}{2}$ tons per square inch without visibly stretching, and when no jar was given to the bars they would support this strain for a week. Upon any vibration, however, the bars immediately took a permanent set.

"Under strains, however, considerably within the elastic limit, a gradual rearrangement of the particles of the iron commences; and if the strain be continued sufficiently long, permanent set will after a while take place. The late Monsieur Vicat, whose work on limes and mortar is so well known, began as early as 1830 to investigate the effect of continued strains on unannealed iron wire. He applied various strains to similar wires of a known breaking strength, and continued these strains from July, 1830,

to October, 1833. One wire was strained to one-fourth its breaking weight, but beyond the elongation which at once took place no additional stretching occurred in thirty-three months. A second wire was strained to one-third of its breaking weight, and in thirty-three months it stretched at the rate of $2\frac{3}{4}$ parts in every 1,000 parts of its length, this stretching being additional to that which took place as soon as the weight was applied, but which, of itself, was not sufficient to immediately produce any permanent set. Under a strain of one-half the breaking weight another wire stretched rather more than 4 parts in every 1,000 parts of its length. Under a strain of three-fourths of the breaking weight, a fourth wire stretched, in thirty-three months, $6\frac{1}{2}$ parts in every 1,000 parts of its length, and then broke, which circumstance terminated the experiments. Monsieur Vicat's account of them appeared in the fifth volume of the second series of the '*Annales de Chimie et Physique*.' It is to be regretted that, in place of the constantly recurring experiments upon the breaking strength of iron, and which, as is already beginning to be understood, give us but a very partial knowledge of its available working properties, we have not a larger experimental acquaintance with the continued supporting power of iron, as afforded by experiments similar to M. Vicat's. Mr. Fairbairn, it is true, made an extensive series of experiments between the years 1837 and 1842, to ascertain how long bars of cast iron would support weights equal to about 19-20ths of their breaking weight. By taking care to prevent any vibration in or about the bars, several of them continued, for five years and upwards, to support nearly their full breaking weight. Their deflection steadily increased, however, during the whole time, and Mr. Fairbairn has stated that some of these bars afterwards broke with but 1-20th of their original breaking weight. As bearing upon the last-mentioned circumstance, it may be remarked that M. Vicat, writing in 1833, observed that Monsieur Henri, an engineer serving in Russia, had already shown that iron which had once withstood a great proof strain often broke sometime afterwards under a much less strain. This fact must indeed have been known to practical men even earlier than in 1830.

"Now, in employing iron in any structure where it is subjected to strain, we seek to keep within its limit of elasticity.

Yet not only have we but a comparatively small number of recorded experiments to show us what this limit is, even under a single and temporary strain, but we have, at least, the result of M. Vicat's experiments to show us that we cannot depend upon anything like this limit under a long-continued strain. What experimental knowledge we have goes to show that the original elastic limit of iron is greater when hammered than when rolled, but we are unable to count with any degree of certainty upon the ultimate superiority of hammered iron, in this respect, after long-continued strain. As a rule, also,—the abundant evidence of which it is not, perhaps, necessary to introduce into the present paper—all harsh, hard, crystalline irons have a higher elastic limit, in proportion to their breaking strength, than soft, ductile, highly fibrous irons—like Swedish bar, for example;—that is to say, the harder irons will bear a greater strain before taking a permanent set, although, as we shall presently have occasion to inquire, it may not follow that they are really superior to other irons which are more readily stretched, and which, indeed, may have an even less breaking weight. What information we have goes to show that there is no settled relation between the elastic limit and the breaking weight of iron; the former is much more variable than the latter, and can hardly be expressed at all as an average result, ranging, as it does, from less than one-fourth to more than two-thirds of the breaking weight: or if the elastic limit be taken irrespective of the breaking weight, the instances already cited show that the former varies from $3\frac{1}{4}$ tons up to $24\frac{1}{2}$ tons per square inch in different qualities of iron, although the range in ordinary bar iron and plate iron is not nearly as great. Now, no engineer, in apportioning the strains in a structure, would think of working up to, or near to, the breaking strength of iron. His object is to keep within the elastic power of the material, not merely as ascertained by a single strain of a few minutes' duration, but the continued elastic power of the iron as exerted through a very long series of years. We ought by this time to have hundreds of trustworthy experiments upon this point where there is now one. If the safe working strength of a metal is limited, as it would appear to be, by its measure of permanent perfect elasticity, we may say that we hardly know, even yet, what is the strength

of the materials we are constantly dealing with, notwithstanding that not a year passes without some addition to our stock of knowledge of breaking weights.

"While we are about considering the permanent injury which iron suffers when strained beyond its elastic limit, it is to be understood that iron may be strained for a short time almost up to the breaking point without in the least diminishing its strength under a breaking weight subsequently applied. Indeed, in gradually applying the breaking strain to any sample of iron, it is clear that it must have borne 10 tons before it is subjected to a strain of 15 tons, and that it must have borne 15 tons before it is strained to 20 tons, and so on. Not only is this the case, but after a bar of iron has been actually broken under a tensile strain, the two broken portions of the bar will almost always require a still higher strain to break them. The weakest spot in the bar will fail first, and although the breaking strain will at the same time permanently stretch the bar throughout its whole length, the iron on each side of the fracture will still have its original breaking strength. Professor Barlow's Treatise on the Strength of Materials contains the results of several experiments made at Woolwick Dockyard, as follow:—

"A bolt of Solly's patent iron was nicked at one place, and then broken by a strain of 26·7 tons per square inch. One of the pieces was then tried and broke at $29\frac{1}{4}$ tons. In the next experiment a bar of the same iron was first broken with $23\frac{1}{2}$ tons per square inch, then again with $26\frac{1}{2}$ tons, a third time with $26\frac{1}{2}$ tons, and a fourth time with $25\frac{3}{4}$ tons.

"Mr. Thomas Lloyd, engineer to the Admiralty, made a like series of experiments a few years ago, on ten bars of SC crown iron, $1\frac{3}{8}$ in. in diameter, and $4\frac{1}{2}$ ft. long. The mean breaking weight at the first breakage was 23·94 tons per square inch. At the second breakage, with pieces 3 ft. long, the mean strength was 25·86 tons per square inch. At the third breakage, with pieces 2 feet long, 27·06 tons per square inch; and at the fourth breakage with 15 inch lengths, 29·2 tons per square inch. Mr. Lloyd's experiments have been held to show that iron was actually strengthened by stretching it, or, in other words, that by *destroying* the cohesion at one point, the cohesion was *everywhere* else increased. A more obvious explanation is, that the

bars first broke at the weakest part, then again at the next weakest part, and so on. A variation of from 23·94 tons to 29·2 tons in the strength of the same bar is undoubtedly large, the greater strength being 22 per cent. more than the lesser, a difference which appeared to exist in each of the ten bars tried. It is well known, however, that hardly any two bars of iron have exactly the same strength, and Mr. William Roberts, manager of Messrs. Brown, Lenox, and Co.'s extensive chain cable works at Millwall, has cut a 12 ft. bar of iron into 2 ft. lengths, and found, on testing, that there was a difference of strength of 20 per cent. between the strongest and the weakest of these pieces. In the experiments of the Railway Iron Commission upon the extension of cast iron, the strength of Lowmoor cast bars was 7·325 tons per square inch at the first, and 8·152 tons at the second breaking. Blaenavon iron broke with 6·551 tons per square inch at the first, and 6·738 tons at the second breakage. Gartsherrie iron broke with 7·567 tons per square inch at the first, and 8·475 tons at the second breakage. Other cast iron bars of a certain mixture broke with 6·6125 tons per square inch at the first, and 6·777 tons at the second breakage, the latter being at an unsound place. Upon these results the commissioners remarked that 'it would appear that iron, repeatedly broken, becomes more tenacious than it was originally. This erroneous conclusion may be obviated by considering that it would be very difficult, if not impracticable, to obtain cast-iron bars perfectly sound and 50 ft. long. Fracture may be supposed to take place the first time at the largest defect, and subsequently at those smaller, until, finally, none remain.' It is not intended, however, in the present paper, to entirely deny that the breaking strength of iron may be actually increased by being stretched when cold; and this point may be left as an open question. That iron is so strengthened derives some probability from the known fact that its strength is greatly increased by being drawn cold into wire, and also by cold rolling. When heated moderately, or to less than a dull red, and then stretched, iron is strengthened throughout. This treatment is known as *thermo-tension*; and in an extensive course of experiments made about twenty years ago by Professor Walter R. Johnson, for the United States Government, a total gain of nearly 30 per cent. in strength

and length, taken together, was estimated to have been obtained with a variety of irons. A bar of iron, having a strength of 60 tons, was heated to upwards of 500 deg., and then stretched by $6\frac{1}{2}$ per cent. of its length, when it acquired a strength of 72 tons. Captain Blakely has lately proposed the same treatment of iron, and his experiments, it is understood, corroborate those of Professor Johnson. All the links made for the four great pitch chains employed, with the steamship Great Britain's engines, for getting up the speed of the screw, were stretched $\frac{1}{8}$ in. while at a dull red heat.

"But from what has been said, it is not to be supposed that iron is not injured by excessive strains, notwithstanding that the metal strained may, when tried immediately afterwards, still retain its full breaking strength. The injury will appear when a subsequent working strain is long continued; and even without waiting for this, it will be found that the strained iron has been deprived of a large part, if not the whole, of its natural elasticity. In a paper of great value, read nearly seven years ago before the Royal Irish Academy, and afterwards published in a quarto volume, entitled, 'On the Physical Conditions involved in the Construction of Artillery,' Mr. Robert Mallet has laid down a useful measure of the working and ultimate strength of iron. Poncelet had already employed coefficients which indirectly expressed, not merely the elastic limit and breaking strength of iron, but the range also through which the force acted in each case in reaching these limits. Mr. Mallet has adapted these coefficients to the English standard of mechanical work, to wit: 'foot-pounds;' and he represents the structural value of different materials, or of various qualities of the same material—in one case by the product of the elastic load in pounds into half the range, in feet or parts of a foot, through which it acts; and in the other case by the breaking weight in pounds multiplied also by half the range, in feet or parts of a foot, through which it acts. Mr. Mallet employs Poncelet's coefficients, as follows:—

T_e	=	foot-pounds	in reaching elastic limit of tension.
T_r	=	" "	to produce rupture by tension.
T^e_c	=	" "	in reaching elastic limit in compression.
T^r_c	=	" "	to produce crushing.

One half the weight into the whole extension, or, what is the

same thing, the whole weight into half the extension, is adopted because the force gradually applied to break a bar must increase from nothing to the breaking weight. Upon Dr. Hooke's law, *ut tensio sic vis*, the weight of a grain will in some minute degree deflect or extend the heaviest bar of iron, and the deflection or extension will increase progressively with the weight applied, up to rupture. Therefore, if a bar be stretched 1 ft., and then broken with a weight of 33,000 lb., the work done will be the mean of zero, and 33,000 lb. into 1 ft., or 16,500 foot-pounds. This, as has been said, is the work done in the case of a gradually applied strain. If, however, the weight be applied without impact, but at the same time instantaneously, upon the bar, it will, so long as the limit of elasticity is not exceeded, and supposing the bar to have no inertia, produced twice its former deflection, and, therefore, twice the ultimate strain. For the weight, in falling through the distance of the deflection due to the load at rest, will acquire momentum sufficient to carry it through an additional distance equal to that of the static deflection. This may be best demonstrated experimentally with the aid of a spring balance. If upon the plan of a balance sufficiently strong to weigh up to 40 lb., a weight of 15 lb. be placed, and this be then lifted to zero on the scale and there released, it will descend, momentarily, to nearly 30 lb. on the scale, and if there were no opposing resistances and the spring had no inertia, it would descend to exactly 30 lb. In the actual application of strains in practice a weight is never thus applied, but a consideration of what would occur under such circumstances is sufficient to show how important it is that vibratory action be not overlooked in considering the strains on bridges. It is to be remembered that this action of suddenly applied loads is only manifested in the case of the application of weights; for if the strain be produced by the sudden admission of steam or any other practically imponderable body, no additional deflection will take place beyond that due to the pressure acting statically. If steam pressure acted in the same manner in this respect as a weight, the steam indicator would show nearly or quite double the pressure acting effectively within the cylinder of the engine.

"It will not be attempted in the present paper to enter fully into the application of the coefficients adopted by Mr. Mallet

for there are objections against, as well as reasons in favour of, their application. It is evident that $T r$ may be the same in two cases—in one of which a high breaking weight is exerted through a very short distance, and in the other of which a low breaking weight produces stretching through a correspondingly greater distance. But this coefficient does possess a value in taking account of the combined cohesive force and extensibility of iron, instead of the breaking strength alone. As Mr. Mallet justly observes, glass has a high cohesive force, and is, nevertheless, useless under strain, owing to its brittleness, while caoutchouc has great extensibility or toughness with but slight cohesion. The products, therefore, expressed by the coefficients in question do not afford a complete notion of the practical value of a given material unless the factors whereby these products are obtained are also given. The elastic limit of iron, however low, is not to be exceeded in practical use, whatever its range of elasticity may be; nor does it appear prudent to work into the neighbourhood of a high elastic limit when the elastic range is known to be small. It is not to be understood that the coefficients in question are intended to apply otherwise than in comparison of bars of equal length, else it would result that the measure of T^e in a bar 50 ft. long, was one hundred times greater than that of a bolt 6 in. long, and of the same material and sectional area. For the purposes of the engineer a long bolt is not only no stronger than a short one; but, as it can be no stronger than its weakest part, it will follow that the average strength of 100 bolts 6 in. long, is likely to be greater than that of a single bolt of the same diameter and 50 ft. long. Every engineer must be aware of the importance of toughness in combination with cohesive strength in iron, but we need much more extensive and accurate information as to the former; and a consideration of Mr. Mallet's coefficients should lead to additional experiments being undertaken. It is but right to mention here that, in 1848, Mr. Homersham Cox contributed a paper to the *Civil Engineers' and Architects' Journal*, in which he represented the mechanical work, in foot-pounds, expended in deflecting a girder, the work being expressed by the product of half the weight into the range of deflection. Mr. Kirkaldy, proceeding upon an independent course of inquiry, but with the same object as that pursued by

Mr. Mallet, has lately published the results of a most important series of experiments, which are the first upon anything like an extensive scale, to take into account the combined cohesive force and extensibility of iron and steel. Mr. Kirkaldy experimented upon many hundreds of specimens, but he did not ascertain their limit of elasticity. He has given both the original dimensions and cross sectional area, and the dimensions and area after fracture; and he has also given the amount of elongation at fracture, although he did not ascertain the extension of the elastic limit. The reduction of diameter of a bar at the point of fracture serves to give a practical man a good idea of the quality of the iron, but it does not admit of an expression of the mechanical work done in producing fracture, as does the combined breaking weight and linear extension. In tearing a bar in two, also, we have to consider the permanent stretch communicated to all parts of the bar alike, and the additional stretch at and near the point of fracture. That part of the stretching which extends uniformly throughout the whole bar would, we may suppose, be exactly proportional to the length of the bar; while that part of the stretch which takes place close to the point of fracture would, we may also suppose, be a fixed quantity, whatever might be the length of the bar. Mr. Kirkaldy's specimens of iron and steel varied from 2.4 in. to 8.2 in. only in length, and with these the ultimate elongation at fracture varied from nearly nothing to 27 per cent. of the original length, whereas longer bars would have shown a proportionally less elongation. The samples which hardly elongated at all were of puddled steel-ship plates. One sample, which bore 63,093 lb. per square inch of the original area, stretched before breaking but the 1-20th part of an inch in a length of 7.6 in., or less than 7-10ths of 1 per cent. of the length. Adopting Mr. Mallet's coefficient, the structural value of such a material would be almost nothing. In fact, Mr. Kirkaldy found the puddled steel plates, throughout, to have much less extensibility than cast-steel plates, while the former, also, were of very irregular breaking strength. The interest attached to the subject of puddled steel may possibly serve as a justification for mentioning this fact, although foreign to the object of the present paper, which has to deal with iron.

"We have, up to this point, considered the elastic limit or permanent supporting power of iron under a single application of strain, extending in some cases over a few minutes, and in others over some months. We have very little experimental knowledge as to the extent to which we may approach the elastic limit under continued strains; but there is a probability that a continuous strain much exceeding one half of the elastic limit would be attended with gradually progressive permanent set. At the same time, with good iron, possessing a fair amount of extensibility, a single temporary strain, producing a slight or even considerable permanent set, may not diminish materially the strength expressed by Mr. Mallet's coefficient $T r$, and the iron may still hold up indefinitely with an ordinary load considerably within the limit of elasticity. But, apart from the consideration of the time through which a strain acts, we have also that of the frequency with which the load is applied and removed. Mr. Fairbairn loaded cast-iron bars to upwards of nine-tenths of their breaking weight, and this load remained on from five to seven years before the bars broke down; but with a repeated application and removal of load, the Iron Commission experiments showed that iron bars, when repeatedly deflected by impact through one half the distance due to their breaking weight, broke down after from 130 to 4,000 applications of the strain. Mr. Fairbairn communicated some of the results of an important series of experiments to the British Association at the Manchester meeting, 1861, from which it appeared that a large model of a wrought-iron plate girder withstood, without injury, 1,000,000 applications of a load equal to one-fourth its breaking weight, and afterwards 5,175 applications of one-half its breaking weight, when it broke down. The model was then repaired, and 25,900 applications of two-fifths its breaking weight, and afterwards nearly 3,000,000 applications of one-third its breaking weight, were made, it was said, without injury, although neither the deflections nor the permanent set were given. We know that iron alters its form, temporarily, during the application of very moderate strains, the elasticity of good iron being generally observable with strains of one ton per square inch. And we know that its form is permanently changed, both immediately on exceeding the limit of elasticity, and gradually under strains nearly

approaching that limit. There clearly must be a rearrangement of the particles of iron always going on where the strain is great; and as we know that when even a more moderate strain is eased off the iron tends to resume its original form, it appears incontestible that final injury must result under what may appear moderate, although irregular loads—say one-third, or even rather less of the breaking weight. Iron, it is still to be remembered, has not been employed long enough for purposes of construction to enable us to compare its endurance with masonry, of which there are abundant examples still perfect after many hundred years. At the same time, it must not be forgotten, that, while we can never know the absolute strength of a bar of iron without destroying it under strain, neither can we always infer its strength from its deflection, or apparent range of elasticity; for we are not yet secure against flaws or those other faults of molecular structure which Mr. Mallet so well describes as ‘planes of weakness.’ A bar of iron may have a general strength of 22 tons per square inch, except at a single point in its length, where, for an almost inappreciable linear distance, the strength may not exceed 10 tons. If the bar be broken this fault will be detected, but hardly, if at all, otherwise; for under a strain of even 8 tons or 9 tons, the extension at the precise point of weakness would be so slight as to be quite overlooked in a general observation of the total deflection or extension.

“In this fact, which was mentioned thirty years ago by M. Vicat, and in the known effects of suddenly applied strains, vibration, impact, &c., we have abundant reason for extreme caution in the use of iron for permanent structures of any kind. It can hardly be said that the Board of Trade limit of 5 tons, arbitrary as it is, is too moderate, although there should be some account taken of the known quality of the iron to which this strain is to be applied; and it may not be necessary to adopt an unlikely load as that which is to produce the maximum strain of 5 tons. The recent discussion as to the security of Chelsea Bridge affords much suggestive material upon these points.

“The application of iron to bridges, especially to those of large span, necessarily requires the most careful consideration in apportioning the strains, since every pound of metal not brought

into effective action, is so much dead weight or useless load—being not only misapplied of itself, but requiring additional material to support it. In considering the strains upon iron, therefore, reference has been more particularly made in the present paper to its employment in bridges; but in the case of boilers, iron ships, cranes, ordnance, railway bars, warehouse girders and columns, roofs, engine beams, and in many other applications, the most careful distribution of material and adjustment of strains is of very great importance. Iron is, perhaps, more severely strained in steam boilers than in other structures. In the case of locomotive engines, there is a disposition to employ still larger boilers and to carry still greater pressures. With 50 in. boilers, formed of 7-16 in. plates, double riveted, and carrying, as is now not usual, from 130 lb. to 140 lb. pressure, there is at the higher limit a circumferential strain of $5\frac{1}{2}$ tons per square inch at the joints, and a longitudinal strain of nearly two tons per square inch along the whole length of the boiler, the resulting strain at the joints being nearly six tons per square inch. This strain is constantly maintained with plates ranging from 21 tons to 24 tons in strength, and under all the contingencies of corrosion, incessant vibration, and occasional sudden exaltations of pressure due to the instantaneous production of steam upon overheated tubes or plates. In many cases we have 4 ft. boilers with $\frac{3}{8}$ in. plates, single riveted, and worked at 120 lb., corresponding to a strain of at least $6\frac{1}{2}$ tons per square inch at the joints of the boiler when new, the circumferential and longitudinal strains being both taken here into account. Put under this strain when new, many locomotive boilers are worked in all from ten to twenty years, and often from three to seven years, without any internal examination of the plates. It is not remarkable, therefore, that explosions are becoming so frequent.

“We may regard with much hope the increasing use of steel in large masses, as produced by Krupp and by Mr. Bessemer, and others whose discoveries have already effected a great economy derate strainuction of that material. Although a departure from able with st of the present paper, it is interesting also to refer to that its formation of phosphorised copper, as now produced by the ceeding the l and other coppermasters. It was announced, about

three years ago, as a new discovery by Mr. Abel, chemist to the War Department, that the addition of from 2 to 4 per cent. of phosphorus to copper greatly increased its density and strength. There is no doubt of the large advantage of this combination, although it was discovered in the last century and made publicly known sixty years ago. A French chemist, M. Sage, contributed a paper upon this subject to the *Journal de Physique*, and which was translated into the 20th volume of the *Philosophical Magazine*, for 1805. By combining the maximum quantity of phosphorus with copper, the latter acquired the hardness, grain, and colour of steel; and although M. Sage had already kept the compound for fifteen years, it had suffered no change from exposure to the air. It was easily turned and took a fine polish. It may yet be found that copper thus treated is the best material for many of the purposes of the mechanical engineer.

"In conclusion, it must be regretted, if not indeed, deplored, that our exact knowledge of the permanent supporting power of iron is so limited. The present paper, it is feared, will hardly fulfil its title, which may have led to the expectation that some definite relation would be assigned between the safe load and the ultimate strength of iron. Even at the risk, however, of leaving the subject as the author found it, he indulges the hope that the considerations which have been touched upon may induce closer observation and inquiry into the real working properties of iron, as distinguished from its ultimate strength. The question involved in this subject does not appear to be one which admits of solution by a reference to any known natural law, nor does it appear that it can be disposed of by mathematical investigation, but our only safe conclusions must be derived from the results of protracted, varied, and repeated experiment. In the meantime common prudence requires that we ascertain, with as much accuracy as possible, the elastic powers of every given kind of iron proposed for permanent works, and that we then so proportion the parts that the working strain shall never much exceed one half the elastic limit—a ratio which will correspond, according to the variable quality of iron, with a load of from 1-8th to 1-4th its breaking strength."

In testing iron work on railway bridges no special regulations are laid down in this country, the general course pursued being

to cover the bridge from end to end with locomotive engines in heavy working trim, and to gauge accurately the deflection. In Prussia a question is raised relative to the different regulations for testing railway bridges; as to whether it is safe to assume a maximum strain of 10,000 lbs., or about 5 tons English, as in France only 8,200 lbs. are allowed. The assumption is that it is perfectly so. From the experiments made on the deflections of different constructions of girders, it is found that the same depends wholly on the proportions of each construction. "Calling the central deflection f , the span l , modulus of elasticity E , the height between the centres of top and bottom flanges h , the strain on the flanges k , the weight of the structure itself p , and the maximum load per foot run p^1 , while p^2 = a similar but smaller load, P = the maximum load in the centre, and P^1 = a smaller central load; then we have for smaller bridges,

$$+ \frac{P^1 l^2}{6 P E h} k.$$

For larger bridges, the following formulæ are to be used, when—

$$A = \frac{p^2 l^2 k}{(p + p^1) E h}$$

For parabolical girders, $f = \left(.3456 + \frac{h^2}{l^2} \right) A$.

For lattice girders of same section throughout, $f = \left(.2083 + \frac{h}{4 l} \right) A$.

For lattice girders of varying sectional area, $f = \left(.25 + \frac{h}{2 l} \right) A$.

For a pair of girders loaded on one bay, $f = \left(.146 a + \frac{h}{3 l} \right) A$.

where A signifies the relative proportion between the largest and smallest sectional areas of the flanges."

In concluding this important subject we shall submit to our readers the following valuable paper, read by Mr. David Kirk-

aldy before the Institution of Engineers in Scotland. The paper throughout abounds with experimental *facts*, and is therefore to be implicitly relied upon.

"Mr. Kirkaldy exhibited several cases of the fractured specimens upon which his experiments were made; and, by way of introduction to the discussion, there were read from his Treatise the following conclusions arrived at by Mr. Kirkaldy in the course of his inquiry:—

1. The breaking strain does *not* indicate the quality, as hitherto assumed.

2. A *high* breaking strain may be due to the iron being of superior quality, dense, fine, and moderately soft, or simply to its being very hard and unyielding.

3. A *low* breaking strain may be due to looseness and coarseness in the texture, or to extreme softness, although accompanied by very close and fine quality.

4. The contraction of area at fracture, previously overlooked, forms an essential element in estimating the quality of specimens.

5. The respective merits of various specimens can be correctly ascertained by comparing the breaking strain *jointly* with the contraction of area.

6. Inferior qualities show a much greater *variation* in the breaking strain than superior.

7. Greater differences exist between small and large bars in coarse than in fine varieties.

8. The prevailing opinion of a rough bar being stronger than a turned one is erroneous.

9. Rolled bars are slightly hardened by being forged down.

10. The breaking strain and contraction of area of iron plates are greater in the direction in which they are rolled than in a transverse direction.

11. A very slight difference exists between specimens from the centre and specimens from the outside of crank-shafts.

12. The breaking strain and contraction of area are greater in those specimens cut lengthways out of crank-shafts than in those cut crossways.

13. The breaking strain of steel, when taken alone, gives no clue to the *real qualities* of various kinds of that metal.

14. The contraction of area at fracture of specimens of steel must be ascertained as well as those of iron.

15. The breaking strain, *jointly* with the contraction of area, affords the means of comparing the peculiarities in various lots of specimens.

16. Some descriptions of steel are found to be very hard, and, consequently, suitable for some purposes; whilst others are extremely soft, and equally suitable for other uses.

17. The breaking strain and contraction of area of *puddled*-steel plates, as in iron plates, are greater in the direction in which they are rolled; whereas in *cast*-steel they are less.

18. Iron, when fractured suddenly, presents invariably a crystalline appearance; when fractured slowly, its appearance is invariably fibrous.

19. The appearance may be changed from fibrous to crystalline by merely altering the shape of the specimen so as to render it more liable to snap.

20. The appearance may be changed by varying the treatment so as to render the iron harder and more liable to snap.

21. The appearance may be changed by applying the strain so suddenly as to render the specimen more liable to snap, from having less time to stretch.

22. Iron is less liable to snap the more it is worked and rolled.

23. The 'skin' or outer part of the iron is somewhat harder than the inner part, as shown by appearance of fracture in rough and turned bars.

24. The mixed character of the scrap iron used in large forgings is proved by the singularly varied appearance of the fractures of specimens cut out of crank-shafts.

25. The texture of various kinds of wrought iron is beautifully developed by immersion in dilute hydrochloric acid, which, acting on the surrounding impurities, exposes the metallic portion alone for examination.

26. In the fibrous fractures the threads are drawn out, and are viewed externally, whilst in the crystalline fractures the threads are snapt across in clusters, and are viewed internally or sectionally. In the latter cases the fracture of the specimen is *always* at right angles to the length; in the former it is more or less irregular.

27. Steel invariably presents, when fractured slowly, a silky fibrous appearance; when fractured suddenly, the appearance is invariably granular, in which case also the fracture is always at right angles to the length; when the fracture is fibrous, the angle diverges, always more or less from 90 deg.

28. The granular appearance presented by steel suddenly fractured is nearly free of lustre, and unlike the brilliant crystalline appearance of iron suddenly fractured; the two combined in the same specimen are shown in iron bolts partly converted into steel.

29. Steel which previously broke with a silky fibrous appearance is changed into granular by being hardened.

30. The little additional time required in testing those specimens, whose rate of elongation was noted, had no injurious effect in lessening the amount of breaking strain, as imagined by some.

31. The rate of elongation varies, not only extremely in different qualities, but also to a considerable extent in specimens of the same brand.

32. The specimens were generally found to stretch equally throughout their length until close upon rupture, when they, more or less, suddenly drew out, usually at one part only, sometimes at two, and, in a few exceptional cases, at three different places.

33. The ratio of ultimate elongation may be greater in short than in long bars in some description of iron, whilst in others the ratio is not effected by difference in the length.

34. The lateral dimensions of specimens form an important element in comparing either the rate of, or the ultimate, elongations—a circumstance which has been hitherto overlooked.

35. Steel is reduced in strength by being hardened in water, while the strength is vastly increased by its being hardened in oil.

36. The more highly steel is heated (without, of course, running the risk of being burned) the greater is the increase of strength, on its being plunged into oil.

37. In a highly converted or hard steel, the increase in strength and in hardness is greater than in a less converted or soft steel.

38. *Heated steel*, by being plunged into oil, instead of water,

is not only considerably *hardened*, but *toughened* by the treatment.

39. Steel plates, hardened in oil, and joined together with rivets, are fully equal in strength to an unjointed soft plate, or the loss of strength by riveting is more than counterbalanced by the increase in strength by hardening in oil.

40. Steel rivets, fully larger in diameter than those used in riveting iron plates of the same thickness, being found to be greatly too small for riveting steel plates, the probability is suggested that the proper proportion for iron rivets is not, as generally assumed, a diameter equal to the thickness of the two plates to be joined.

41. The shearing strain of steel rivets is found to be about a fourth less than the tensile strain.

42. Iron bolts, case-hardened, bore a less breaking strain than when wholly iron, owing to the superior tenacity of the small proportion of steel being more than counterbalanced by the greater ductility of the remaining portion of iron.

43. Iron highly heated, and suddenly cooled in water, is hardened, and the breaking strain, when gradually applied, increased, but, at the same time, it is rendered more liable to snap.

44. Iron, like steel, is softened, and the breaking strain reduced, by being heated and allowed to cool slowly.

45. Iron, subjected to the cold-rolling process, has its breaking strain greatly increased by being made extremely hard, and not by being 'consolidated,' as previously supposed.

46. Specimens cut out of a crank-shaft are improved by additional hammering.

47. The galvanizing, or tinning, of iron plates, produces no sensible effects on plates of the thickness experimented on. The results, however, may be different should the plates be extremely thin.

48. The breaking strain is materially affected by the shape of the specimen. Thus the amount borne was much less when the diameter was uniform for some inches of the length than when confined to a small portion—a peculiarity previously unascertained, and not even suspected.

49. It is necessary to know correctly the exact conditions under

which any tests are made, before we can equitably compare results obtained from different quarters.

50. The startling discrepancy between experiments made at the Royal Arsenal, and by the writer, is due to the difference in the shape of the respective specimens, and not in the difference in the two testing machines.

51. In screwed bolts, the breaking strain is found to be greater when old dies are used in their formation than when the dies are new, owing to the iron becoming harder by the greater pressure required in forming the screw thread when the dies are old and blunt, than when new and sharp.

52. The strength of screw-bolts is found to be in proportion to their relative areas, there being only a slight difference in favour of the smaller, compared with the larger, sizes, instead of the very material difference previously imagined.

53. Screwed bolts are not necessarily injured, although strained nearly to their breaking point.

54. A great variation consists in the strength of iron bars which have been cut and welded; while some bear almost as much as the uncut bar, the strength of others is reduced fully a third.

55. The welding of steel bars, owing to their being so easily burned by slightly overheating, is a difficult and uncertain operation.

56. Iron is injured by being brought to a white or welding heat, if not at the same time hammered or rolled.

57. The breaking strain is considerably less when the strain is applied suddenly, instead of gradually, though some have imagined that the reverse is the case.

58. The contraction of area is also less when the strain is suddenly applied.

59. The breaking strain is reduced when the iron is frozen; with the strain gradually applied, the difference between a frozen and unfrozen bolt is lessened, as the iron is warmed by the drawing out of the specimen.

60. The amount of heat developed is considerable when the specimen is suddenly stretched, as shown in the formation of vapour from the melting of the layer of ice in one of the specimens, and also by the surface of others assuming tints of various shades of blue and orange, not only in steel, but also, although in a less marked degree, in iron.

61. The specific gravity is found generally to indicate pretty correctly the quality of specimens.

62. The density of iron is *decreased* by the process of wire-drawing, and by the similar process of cold-rolling, instead of *increased*, as previously imagined.

63. The density in some descriptions of iron is also decreased by additional hot-rolling in the ordinary way; in others, the density is very slightly increased.

64. The density of iron is decreased by being drawn out under a tensile strain, instead of increased, as believed by some.

65. The most highly converted steel does not, as some may suppose, possess the greatest density.

66. In cast steel the density is much greater than in puddled steel, which is even less than in some of the superior descriptions of wrought iron.

“The breaking strain per square inch of wrought iron is generally stated to be about 25 tons for bars and 20 tons for plates. This corresponds very nearly with the results of the writer’s experiments, of which the following table presents a condensed summary:—

	Lbs. Highest.	Lbs. Lowest.	Lbs. Mean.	Tons.
188 Bars, rolled,	68,848	44,584	57,555	= 25½
72 Angle-iron, &c.,	63,715	37,909	54,729	= 24½
167 Plates, lengthways,	62,544	37,474	50,737	} = 21½
160 Plates, crossways,	60,756	32,450	46,171	

“Although the *breaking* strain is generally assumed to be about 25 tons for bars and 20 tons for plates, very great difference of opinion exists as to the amount of *working* strain, or the load which can with safety be applied in actual practice. The latter is variously stated at from a third to a tenth. It will be observed that whilst much discussion has arisen as to the amount of working strain, or the ratio the load should bear to the breaking strain, the important circumstance of the *quality* of the iron, as influencing the working strain, or the ratio the load should bear to the breaking strain, the important circumstance of the *quality* of the iron, as influencing the working strain, has been overlooked. The Board of Trade limits the strain to five tons, or 11,200 lbs. per square inch.

"It must be abundantly evident, from the facts which have been produced, that the breaking strain, when taken alone, gives a false impression of, instead of indicating, the real quality of the iron, as the experiments which have been instituted reveal the somewhat startling fact, that frequently the inferior kinds of iron actually yield a higher result than the superior. The reason of this difference was shown to be due to the fact, that whilst the one quality retained its original area, only very slightly decreased by the strain, the other was reduced to less than one-half. Now, surely this variation, hitherto unaccountably completely overlooked, is of importance, as indicating the relative hardness or softness of the material, and thus, it is submitted, forms an essential element in considering the safe load that can be practically applied in various structures. It must be borne in mind that although the softness of the material has the effect of lessening the amount of the *breaking* strain, it has the very opposite effect as regards the *working* strain. This holds good for two reasons: first, the softer the iron the less liable it is to snap; and, second, fine or soft iron, being more uniform in quality, can be more depended upon in practice. Hence the load which this description of iron can suspend with safety may approach much more nearly the limit of its breaking strain than can be attempted with the harder or coarser sorts, where a great margin must necessarily be left.

"Special attention is now solicited to the practical use that may be made of the new mode of comparison introduced by the writer, viz.: *the breaking strain per square inch of the FRACTURED area of the specimen, instead of the breaking strain per square inch of the ORIGINAL area.*

"As a necessary corollary to what he has just endeavoured to establish, the writer now submits, in addition, that the *working* strain should be in proportion to the breaking strain per square inch of fractured area, and not to the breaking strain per square inch of original area, as heretofore. He does not presume to say what that ratio should be, but he fully maintains that some kinds of iron experimented on by him will sustain with safety more than double the load that others can suspend, especially in circumstances where the load is unsteady, and the structure exposed to concussions, as in a ship, or to vibratory action, as in a railway bridge.

"The writer has not attempted to explain the cause of the mysterious change produced on steel by heating it and plunging it into water, or the no lesser singular result effected by plunging it, when heated, into oil. Neither has he tried to account for the mysterious change produced by subjecting iron to the processes of cold-rolling or wire-drawing. The explanation offered by some, of this difficult question, that the iron or steel are *condensed* by the processes to which they are subjected, is completely contradicted by fact, the metal being actually *expanded*. The aim of the writer being strictly to ascertain facts, and state the conclusions which he considers to be fairly deducible from them, he has not felt himself warranted in attempting to speculate on a subject respecting which so little is yet known.

"In conclusion, the writer ventures only to express a hope that the experiments, on which he has been so long and unremittingly engaged, may not prove wholly unserviceable to practical science and the world at large. The importance of possessing a thorough knowledge of the capabilities and strength of substances on which the lives and property of so many human beings depend, no one will attempt to deny. The only excuse, if, indeed, excuse it can be called, for employing an inferior description of material in the rearing of structures on the stability of which such momentous issues are involved, is ignorance or misapprehension of its proper quality. The writer has endeavoured, by a plain statement of facts, to furnish some information on a subject which seems, until now, to have been denied the attention which its paramount importance demands. Were this question fairly taken up and considered, some security might be afforded against the repetition, in future, of disasters occasioned by its being so often practically ignored. The necessity of using nothing but the very best description of metal, where human life or valuable property is at stake, may, he trusts, come soon to be more generally recognized than it is at present. And an increased demand for the finer varieties may conduce to a generous emulation amongst the manufacturers to improve still further the quality of their productions. Should his labours tend in any way, even the smallest degree, to diminish the annual sacrifice of life and property occasioned by faulty material and workmanship, he will feel *the satisfaction* that they have, at least, not been entirely in vain.

“ Mr. Kirkaldy exhibited 490 selected specimens, which were contained in five cases, namely:—

- In Case I. 9 iron bars, showing elongation and lateral contraction.
1 iron plate, ditto.
1 steel plate, ditto.
- In Case II. 42 steel bars, showing fractures and contraction of area.
105 iron bars, ditto.
- In Case III. 36 steel plates, ditto.
60 iron plates, ditto.
24 angle-iron, &c., ditto.
- In Case IV. 36 iron bars, showing fractures and effects of difference of shape.
40 iron bars, showing fractures and effects of difference of treatment.
12 steel bars, ditto.
10 iron plates, ditto.
15 iron bars, showing fractures and effects of strains suddenly and gradually applied.
- In Case V. 46 iron bars, showing fractures of screwed bolts.
12 iron bars, showing fractures of welded joints.
2 steel bars, ditto.
26 iron bars, showing texture as developed by acid.
8 iron plates, ditto.
1 iron plate, with surface cold-rolled.
4 iron bars, with surface cold-rolled.

“ In the discussion which followed—

“ Mr. Walter Macfarlane said it was well known to all practical workers in steel and iron, that if they attempted to temper some kinds of steel articles in water they cracked ; but that if they did the same thing in oil there was not the same danger of doing so. He did not know whether Mr. Kirkaldy had given, or could now give, an explanation of the cause of the increased strength of steel when tempered in oil, as compared with that tempered in water? He would like to know whether the fibre altered, or what tended to produce the result.

“ Dr. Macquorn Rankine remarked, that Mr. Kirkaldy disavowed in his book any attempt to explain the changes which took place in steel when plunged into water or into oil.

“ Mr. Macfarlane said he thought there was an absolute necessity for their getting at the cause of that important result.

“ Mr. Kirkaldy, in answer to the president, had nothing further to say upon the point.

“ Mr. D. More said that Mr. Kirkaldy invited ‘special attention to the practical use that may be made of the new mode of

comparison introduced by him, viz.: the *breaking strain per square inch of the fractured area of the specimen, instead of the breaking strain per square inch of the original area.* That seemed to be the principal point hinged upon, as it was given in *italics*. Now, he did not think it was even the breaking strain of the *fractured* area that must be considered, for after the iron was broken it drew out a little further. This sort of posterior action was shown in some experiments made by Dr. Rankine and himself in regard to iron and also brick. They found, in crushing the brick, that it withstood a considerable force, and afterwards crumbled away with a less force, thus showing that the breakage had really taken place before the brick had commenced to crumble away. In experimenting with an iron bar, it was observed that the iron drew out and became narrower at one part (as he showed by a sketch on the board) until the strength of the material was overcome. Then, immediately on the iron beginning to break, it drew out before it was finally completely separated, so that the fracture took place when the bar was a little bigger than it finally became. He thought that the truth lay between the two areas—the original and the fractured area.

“Mr. Kirkaldy said he had given the stretched area also in his tables, so that parties could judge of it for themselves. The three areas were given—the original, the stretched, and the fractured areas.

“Mr. W. M. Neilson remarked that Mr. Kirkaldy’s book was a mass of *data* from which to deduce results. He thought it was a very excellent thing that Mr. Kirkaldy had confined himself to giving facts, which would cause his book to be much more relied upon. He believed that Mr. Kirkaldy wished to lay his facts before the Institution for discussion, and that he would not be displeased, although they pulled them about as they liked. Regarding the effects of frost upon iron, upon which point he had never himself been quite clear, it appeared that frost did not affect the strength in a direct strain; but he had always had an idea, that perhaps not the drawing strain, but the breaking strain, was very much affected by frost. They all knew the fear they had of using chains in frosty weather. Now, he supposed that the strength of the chain links was very much diminished *by the frost*, and that the links broke not so much by direct *tension* as by a breaking strain.

"Mr. Kirkaldy said his experiments on the influence of frost were all made with specimens taken from one bar. He regretted that the weather changed before he could carry out his intention of repeating those experiments with bars of various qualities. As the bar experimented upon happened to be of very good quality, perhaps they ought not to draw general conclusions from its behaviour.

"Mr. W. Simons said that in the operations attending upon the placing of a thousand-ton ship on a ship-dock, during one frosty night he had seen three rods $3\frac{1}{2}$ inches in diameter, broken, so that they had to stop and put fire to all the rods and joints, and after that none of the rods broke. In the International Exhibition, he had observed a very good specimen of Swedish iron, which some of the other members might also have seen, which was all crumpled like a hat, it being the bow of a steamer after collision. He did not believe that any Scotch iron would have stood such a test. He was of opinion that the result of Mr. Kirkaldy's investigations would be, that the present system of ship-building would be found to be entirely erroneous, and that for the future iron would be used in ship-building with its longitudinal fibre placed in the direction of the most constant strain, a principle which had hitherto been ignored in marine construction.

"Mr. B. Connor said that some very interesting experiments, which had not been published, had been recently made by Messrs. Naylor and Vickers, at Sheffield, with a view of testing steel, so as to ascertain the best suited for railway axles and tyres. They had found that the material best suited for axles was the worst for standing great tension. They found that steel, which could bear only 35 tons of tension, was the best for journals. They tried steel with 15 cwt. falling from 1 ft. up to 36 ft. The tensional strength of the steel was then increased so as to stand up to 69 or 70 tons, but it broke with the weight falling one-third of the space, and with less than one-half of the weight; and so that that which stood the greatest tension broke with the least concussion. He thought that between the highest and the lowest qualities of steel there was only a difference of one-fourth per cent. of carbon.

"Mr. Kirkaldy thought that these experiments supplied strong

reasons for taking the stretched and fractured areas into account.

"Mr. B. Connor did not think the steel with the greatest amount of carbon, that broke almost short off, would show nearly so great a difference between the fractured and the original areas as the soft steel.

"Dr. Macquorn Rankine concurred in what Mr. W. M. Neilson had said as to the very valuable collection of facts, most of them entirely new, which Mr. Kirkaldy had given in his book. It was a storehouse, from which they could all draw materials, and form their own conclusions upon them. Mr. Kirkaldy had very fairly described those facts, and it was the better that he had not set up any hypothesis upon them. One of the particular things which he (Dr. Rankine) remarked was, that the experiments of Mr. Kirkaldy seemed to point to the conclusion, that a process which many supposed to take place, namely, a change from the fibrous to the crystalline structure, had no real existence; and that the same piece of iron would show a crystalline or fibrous appearance accordingly as it was broken by a stroke or a strain. He came to the same conclusion himself nineteen years ago by experimenting on the fracture of railway axles, which when fitted up seemed to have been quite strong enough. He collected the broken-off journals of such axles; but he was sorry that he could not now produce them, as no means had been taken to prevent the ends getting rusty. But he had made full-sized drawings, coloured from nature, of the more remarkable of them, which he presented to the Institution of Civil Engineers, along with a paper, an abstract of which was published; but the drawings were not published, and remained at that Institution, where they could be seen by any one. He still, however, possessed the originals of those drawings; and if it would be agreeable to this Institution to see them, he would produce them at a future meeting. Of course they were not so satisfactory as the original specimens, or as Mr. Kirkaldy's; but unfortunately the originals had been spoiled by rust. He got the journals of axles that had run two or three years, and had then broken off spontaneously, and almost every one of these showed a fibrous fracture, with here and there a crystalline spot. There was invariably a crack which had eaten in from the shoulder of the journal, and which was perfectly imperceptible until after the fracture took place. The crack seemed

to have gone on until it had reduced the original diameter of the journal to about one-half, and then the axle snapped; but it always presented a fibrous fracture, whilst if the same journals were broken off with a blow of a hammer, they presented crystalline or granular fractures. Accordingly, he had ever since thought it probable that a change from fibrous to crystalline, as supposed, was an erroneous hypothesis; and he believed that many other persons had come to the same opinion, and he was glad that Mr. Kirkaldy's experiments corroborated it. An important point in those experiments was the calling attention to the comparison between the fractured area and the load that caused the piece to give way. Every one knew before, that bars of iron would draw out, especially if soft, before giving way; but never before Mr. Kirkaldy had any one accurately measured the final area to compare that with the load. He thought that there was a great deal in the principle Mr. Kirkaldy laid down as to testing the quality of iron, by the comparison of the breaking strain with the fractured area; but he would not go so far as Mr. Kirkaldy and say that it was the most accurate test, although he had no doubt it was better than comparing the original area with the breaking load. The experiments of Mr. Kirkaldy had substantiated results that had been anticipated by theory. For example, it was a result of theory that the form of the longitudinal section influenced the breaking load per inch of area. Experimentalists, however, had not taken that into consideration before. Experiments were made upon the tenacity of bars that were for a long distance of a uniform diameter, but there had been experiments made with bars shaped so as to have an increasing diameter on both sides of the middle part (as he pointed out on the board), and the result was a great apparent increase of strength. It had been perfectly well understood by writers on the theory of elasticity, that the shape referred to must give apparent increased strength to the narrow portion of the area, as the wider parts on each side resisted the tendency to draw out, which was not the case with the parallel bar. Experimentalists, however, had not taken this into account until Mr. Kirkaldy took it up and arrived at the results detailed in his book. Mr. Kirkaldy showed that the resistance of steel rivets to shearing was about a quarter less than *the tenacity of the steel*. That, also, was anticipated by theory.

There was one very important point upon which Mr. Kirkaldy made some remarks, namely, as to the factor of safety—the ratio in which the breaking load ought to exceed the working load. Mr. Kirkaldy considered that the working load per square inch of the original area of the piece should be a certain percentage of the breaking load per square inch of the contracted area at the instant of being broken. He (Dr. Rankine) concurred in Mr. More's opinion, that the truth lay between the extreme views. He thought it would be going rather too far to make the working load per square inch a certain fraction of the breaking load per square inch of the fractured area. He might call attention to experiments made on the strength of steel by Prof. Tresca, of the French Government Corps of Engineers. They were made upon bars of steel cut out of boiler plates, and they showed the gradual elongation of the bar with the gradual increase of the load. The results were represented by a curve (of a kind sketched on the board by Dr. Rankine), the abscisses of which represented the loads, whilst the ordinates represented the elongations due to the loads. It was found that as the load was increased, the elongation increased at a uniform rate, until it reached a certain point, when there occurred a great increase in the rate of elongation, which was not quite sudden, though nearly so; and there resulted a curve, the early part of which proceeded in a nearly uniform direction, and which merged by a quick bend into a portion proceeding in a different direction corresponding to the more rapid elongation. Now, he thought the point where the change in the curve of elongation occurred was that at which the strength of the material had been overcome. It was very probable that the drawing out, which was so conspicuous in Mr. Kirkaldy's experiments, began at that point, and that the greatly-increased curve of elongation showed that the breaking had begun, and that the bar would break if the same load was simply put on it several times, without being increased, as was seen in Mr. Fairbairn's experiments. The experiments of this class were very interesting, taken in connection with Mr. Kirkaldy's experiments. He thought, then, that the best test of the quality of the material was the strain at which the sudden change of the curve of elongation began; or, if that supposition of his was right, the point at which the drawing out of the fibres commenced. If they

could only make experiments so precisely as to measure the area of the bar at the instant of change, and compare it with the load, and take the corresponding strain per square inch, they would get at the true strength of the material; it would give a result between that of the old method and that of Mr. Kirkaldy's method. But although it was very desirable to obtain such experiments, yet there were difficulties in the way of performing them upon the immense number of materials that Mr. Kirkaldy had experimented upon. The Institution could not be too grateful to him for his labours, for he had collected a mass of facts which were of the highest value in a scientific and practical point of view."

DIVISION EIGHTH.

TIMBER.

On the properties of timber and wood, the following is a thoroughly practical paper by Joseph Justen, which we extract from the '*Builder*:'—

"By wood we understand that portion of a tree between the rind and the marrow, and we have to distinguish the heart from the sap wood. In hotter climates trees generally grow largest. A piece of heart wood is heavier and harder than a piece of sap wood, and a piece cut from near the root will be heavier and stronger than a piece cut from near the top.

"The size to which some trees grow is astonishing. A few famous chesnut trees on Mount Etna measure from 60 to 80 feet in circumference: near Worms, in Germany, grows an elm tree (*Ulmus campestris*), called the Luther tree, 116 feet high and 35 feet in circumference: on the island of Teneriffe, a *dracæna* (dragon tree) is seen, 80 feet high with a diameter of 29 feet. Still larger than these are the mammoth trees (*Wellingtonia gigantea*), and the firs, found in America, some of which are reported to measure 400 feet in height and from 60 to 80 feet in circumference.

"The inner structure of trees is the foundation of all the

singularities of the woods. It is the same in most European and other trees. If we look with the assistance of a magnifying-glass at a cross section, we observe in the centre the marrow, next to it the heart wood, then the sap wood, the cambium, and the bark. From the marrow run out towards the rind thin lines, which are crossed by rings, taking the appearance of the cobweb of a spider. These rings indicate the age of a tree, one being in general added every year. Some trees live very long: for instance, the Adansonian, standing on the banks of the Senegal, is estimated to count nearly 6,000 years.

"The yearly rings stand in close connexion with the development of the leaves: if we find them imperfect, it has been caused by the loss or the freezing of the branches. It might also have been effected by dryness, or by insects and larger animals who live upon and in the trees. Among the most destructive in the animal kingdom which attack trees are enumerated the cockchafer, hornbeetle, the barkscab, the castor, hares, rabbits, squirrels, and deer. In some instances it has been found that the August sap forms in the same year a second ring, by which the age of a larger tree becomes doubtful if it is estimated from its yearly rings. The formation of these rings is not so clearly marked in the wood which has grown in hotter climates. A strange appearance is caused by the unequal width of the rings, and in fact it is never that two of them are found alike, or at least very seldom. This feature, is, however, of value, because one may judge by it upon the physical condition of the wood; and we will, therefore, examine this point more closely.

"The fir, which grows on very dry marl, forms very narrow yearly rings; if on rich or damp marl, they are wide; and when on wet soil, they are again smaller. The common fir, on moor soil, has even smaller yearly rings than if on dry sand or marl. From this it is evident that too wet or too dry a soil is not suitable for the promotion of this tree.

the alder (*Betula alnus*), the willow (*Salix*), and partly, taken in coniferous tree (*Fraxinus*), grow best on wet soil, and thrive thought, then, in standing dry.

was the strain at life of a tree requires a certain amount of light gation began; or, in air, which are necessary, besides the nourishment at which the drawies through its roots from the soil. If a tree

is transferred into a more suitable climate or richer soil, it will naturally improve in condition; but should any element be deficient, we shall notice no improvement, or the tree may improve in one way, such as increase in size, while it suffers on the other hand; for instance, loses in its specific weight. A pine with small yearly rings is of good quality, for we find each spring or summer ring surrounded with riper autumn wood, richly saturated with resin.

"Towards the bark the autumn rings remain about the same thickness, whilst the softer portions are seen larger. A white fir-tree, twenty-five years old, and situate in a tolerably suitable ground, may have a diameter of 3 inches or more, whilst another on dry ground will be but 1 inch thick. With the former the yearly rings will be 2·5 mill., and with the latter 0·16 mill. If we submit a cross section of each under the microscope the former will appear like a net with large pores, while the second looks almost like one solid mass. This fact illustrates the cause for the many accidents which have not their immediate origin in the rotten or bad state of timbers. The greatest attention should be paid to the point in the selection of masts and spars in ship-building yards. The usual width of the rings in the fir, when young, is 2·4 mill., with a slight decrease towards the bark: the smallest rings are found in the Swedish and Russian firs: this may be ascribed to the short summer in those climates: however, they are found similar in more southern climates: therefore the same result is brought forward under different circumstances.

"The leafwoods with large pores deserve special observation. Analogous but opposite to those made with the pines, we notice with them that, although the rings become smaller, yet the quantity or bulk of the porous spring wood does not diminish at the same ratio; therefore, a cubic inch must contain more mass the less we find pores in the same; or, in other words, the broader the yearly rings, so much greater will be the mass of the wood: the reason is, that the pores are considerably smaller on trees with broader yearly rings, and at the same time less numerous. The outer rings of trees are often found almost as porous as the root-wood. This is still more frequently the case with the branches of the trees. If we have, therefore, to select between two oaks, we

shall choose the one with the broader yearly rings, because we shall have in a cubic foot of the same a larger quantity of wood than in the other.

"Should it so happen that a whole forest produces trees with wide yearly rings, and another forest trees with small rings, then the question arises whether the former is caused by the wet condition of the soil; in which case the wood in the first will be more porous and loose than in the latter. We must, therefore, take into consideration the specific weight, as well as the broadness of the rings; and if we find both correspond, then we may conclude that the timber is sound. Wood that has rings of more than 6 mill. wide for a section of some inches, should not be used in building: it is only fit to be burned. Trees which have grown in marsh or clammy soil, along rivers, furnish bad timber.

"If we dissect the stem of a tree throughout, and notice the yearly rings, we find many diversions, for the explanation of which we have to refer to the organization of the growth of the tree.

"In pines we find more regularity in the width of the rings, from the centre towards the bark; this process depends much upon the position of the tree and the surrounding influences. With leafwoods we find a greater variety in the rings, but these as well as the pine have that same feature in common, that the rings increase towards the bark, and that close to the latter they decrease again. The number of branches influence the width of the rings in their position; and if a stem was cut through in its centre, we might then form the relative width of the rings in the various heights, and come to a conclusion as to the cause of their changes. It is necessary to remark, that the assertion that the rings are wider on the south side of a tree than those on the north, is devoid of all truth; still, eccentric trees have broader rings on the projecting side than on the flat side; also inclined stems and branches show them smaller on the upper side. The bark is of importance to a tree: it acts as a protective band for the distribution of the sap, and is therefore necessary for the formation of the yearly rings. If the bark is damaged or split in a certain place, we observe that the next following ring *increases considerably* at this wound: an exception of this is the

almond tree (*Amygdalus*), which bends hollow in the place where the bark has been damaged.

"If we turn our attention to the condition of the woods, and take a cross section of the stem half an inch thick, it will hardly be possible to detect any difference between the younger and the older wood. If we take a stem of the same wood about as thick as an arm, the centre portion will appear dryer and may be called the ripe wood, while the outer portion is charged more with sap, and called sap-wood. With many timbers the heart-wood is of a deeper colour, or between the ripe wood and the sap-wood is a portion of different colour.

"The ripe wood absorbs water less than the sap-wood: it has a greater durability, and it is not so easily decomposed as the latter.

"In some trees the destruction commences with the ripening of the wood; for instance, the Canadian poplar (*Populus*) and the willows (*Salix*), which begin to darken in the centre; and by their smell they indicate their decay.

"The sap-wood of hard wood trees is of little use: it never lasts for any period; and when used it only serves to introduce destructive organs into the better wood.

"When trees arrive at a certain age they should be cut down, if it is intended that their wood should be of good and durable quality. If they are left growing the quantity of wood will certainly increase, but the quality will suffer.

"The limits of the period when the trees are to be felled depends upon the development of their wood.

"The colour is a prominent feature, not only with the various species, but also of the quality of the wood. If the tree is felled in a rainy or damp atmosphere, for instance, during a mild winter season, then the heart of the wood will retain its natural wet colour for a longer period. In a dry spring atmosphere the heart-wood dries sooner, although the sap-wood retains its moisture longer than the ripe wood of the stem: by this latter process the moisture evaporates and draws towards the bark, by which the sap-wood takes the darker colour of the ripe wood. The proper colours of the various woods are only fully developed after they have been exposed to the influence of the atmosphere for some time. The time when the timber is highest in colour

is said to be during the period when the tree is in full bloom, which assertion has, however, not yet been fully verified.

"If the colour of an oak is of one cast, it is a sign of its good condition; but it must be of the same shade in the ripe wood as well as in the various yearly rings: as the shades stand under the influence of action from without, a proper judgment upon the condition of the wood can only be given when the tree is forested. In some instances the scent of woods enables us to pass a judgment upon their condition. Persons who pass in the first spring month a number of old white poplar trees (*Populus alba*), will notice an obnoxious smell: this proceeds from the sap, which flows from the decayed interior to the outside. The pine wood will retain its natural smell for years. Leafwood trees have generally a sour smell, and it is reckoned that the stronger it is the healthier is the wood. Should this smell be faint we may judge that the tree is dying off.

"The sap which circulates in the tree and promotes its life is composed in its main portion of oxygen, hydrogen, carbon, nitrogen, and sulphur. The same forms a considerable body in the green or fresh wood; it changes more or less in the quality of the wood, and the intimate study of its influences is of great technical importance. It has been said that the sap flows out of a tree after it is cut down. From experiments which have been made it resulted in this being the case with very few woods, and not with the majority: with most of them the moisture evaporates.

"The quantity of sap changes very considerably during the season of the year. In elucidation of this a fine example is furnished to us by M. Duhamel de Monceau, and described in his work, 'Exploitation des Bois.' During the years 1732 and 1733 he felled each month eight oaks of equal age, and from the same spot. These were cut immediately into twenty-five pieces, each 3 feet long and 3 inches square (Paris measure), and he obtained the following results:—

340·718	pounds (Paris weight)	in	December.
340·906	"	"	January.
328·031	"	"	February.
331·087	"	"	March.
311·875	"	"	April.
319·500	"	"	May.

297·312	"	"	June.
297·250	"	"	July.
314·469	"	"	August.
306·875	"	"	September.
328·906	"	"	October.
331·000	"	"	November.
(One pound Paris weight—1·0769 avoirdupoise.)			

"From these figures it appears that, during the months of December and January, the trees contain more sap than at any other period. It diminishes in October, November, February, and March; next in April, May, August, and September; and its quantity is least during the months of June and July.

"From another experiment, made in 1737-38 with six stems of young oaks, it was ascertained that the lower portion of the trunk weighed (hydrostatically determined) of the December wood, 1·132; April wood, 1·016; July wood, 1·017.

"This proves that there was most sap in the December wood. The difference between the April and July woods remains doubtful. The same pieces of wood were also weighed when dry, and, compared with the fresh weight, it gave the following result in lb. weight:—

	Green.	Dry.	Loss of Sap.
April wood.....	57·339	41·839	15·500
July wood.....	94·851	68·226	26·625
December wood....	77·062	52·375	24·687

"This shows that the quantity is most in December, and least in July and August. We must not overlook in these cases to take into consideration the influence of dry and wet seasons, by which the sap is materially affected. Contrary to the preceding experiments, the notion prevails that the quantity of sap in a tree is more in the spring than at any other season. Another author, Mr. Th. Hartig, found, after many experiments (which are fully described in Nordlinger's 'Technical Properties of Woods'), that, upon the average, with most woods the greatest moisture is in trees during the months of January and February. He reckons it at 50·05 per cent. During the months of March and April some trees discharge through their bark a quantity of sap, from which one should believe that they were full of it,

while only 47·5 per cent. is really in them. In May and June they hold 48·5 per cent.; in July, during which the yearly ring is formed, 50 per cent.; and in September, when the ring is fully developed, they contain 48 per cent.

"The large amount of sap which is found in stems during the winter months diminishes towards the spring.

"Heavy hard woods lose by drying about one-third of their original weight: lighter woods, poplars, alders, pines, &c., lose from one-third to one-half, which in some degree is dependent upon the soil where they were grown. The bark prevents the sap from running out of the stem; therefore, if pieces were taken from the same stem, some with and others without the bark on, it will be noticed that those without bark will discharge much quicker than the latter. Experiments have also proved that the weight of pieces with their bark on fluctuates, whilst the weight of barked wood steadily diminishes. The cause of this difference is most probably due to the hygroscopicity of the bark to absorb humidity from the atmosphere.

"Wood never loses all its sap: when it becomes air-dry it generally has about 20 per cent. of its weight. It is of importance to know how long various timbers of different dimensions and strengths will take to become air-dry; that is to say, how soon will they arrive at the medium weight which they always maintain, and to which they return whenever the influence of the atmosphere alters it.

"Many mechanics require dry wood for their work, but it is not seldom that they use it before it is properly seasoned.

"I have before alluded to several instances which affect the due seasoning of timber, and from these it is impossible to adopt a general rule, because in each place surrounding influences must be taken into consideration. Let me, however, refer to the cause of the warping of floor-planks, which has its reason,—that the air does not reach the lower side of the deal. It shows itself stronger where the plank has been planed at the top and the lower side has been left in its rough state, by which a larger quantity of moisture is discharged by the outer side, which causes the warping.

"In exposing various woods to the action of water, it will be found that the younger stems are more subjected to its influence,

because it absorbs more water than old wood. For hydraulic constructions, none but well seasoned old hard woods should be used; and the sap wood should also be avoided, because it promotes the decay of the sound parts. The specific weight must next be taken into consideration.

"Most of the woods swim in water. The specific weight of wood is found by taking the dry weight, then thrown into water until quite saturated, after which it is weighed again. We must then weigh it under water. If we then divide with the difference of the second and third weights, which represent the weight of the water displaced by the wood, into the natural dry weight, we obtain the specific weight. This answers in general well enough, but it is not so correct as the process recommended by Mr. Marcus Bull. He justly observes that the wood is liable to swell in the water; and after having taken the dry weight he covered the piece of wood with a varnish having the exact density of the water. This varnish is composed of rosin having a density of 1.079, and wax having a density of 0.967. By this varnish the water cannot penetrate into the wood.

"The solid matter of the wood divested of all cavities is heavier than water, and its density or weight, compared with that of water, varies, according to Rumford, from 1.46 to 1.53.

"It is very difficult to give a general figure for the specific weight of any kind of wood. Pieces from the same tree produce different results, but the following figures give an average weight:—

Ironwood	.	.	.	.	1.210
Greenheart	.	.	.	.	1.200
Sabacue wood	.	.	.	.	1.100
Brazil wood	.	.	.	.	1.100
Ebony	.	.	.	.	1.080
Box	.	.	.	.	1.050
Medlar	.	.	.	.	0.950
Lilac or pipe wood	.	.	.	.	0.930
Oak	.	.	.	.	0.885
Beech	.	.	.	.	0.852
Ash	.	.	.	.	0.845
Yew	.	.	.	.	0.807
Elm	.	.	.	.	0.800
Apple	.	.	.	.	0.733
Fir	.	.	.	.	0.657
Lime	.	.	.	.	0.604
Cypress	.	.	.	.	0.598
Cedar	.	.	.	.	0.561

Poplar (silver)	0.529
Sassafras	0.482
Poplar (common)	0.383
Cork	0.240

"The weight of water for the above is taken at 1,000.

"Experience has shown that the time when trees are felled has much influence upon the condition of the wood. A trial was made in Germany with four pieces of oak, cut down in December, January, February, and March. A tin ring was fixed at one end of each of the four pieces: these rings were filled each with two quarts of water, and it proved that the piece of wood cut in December did not permit any water to pass through its pores.

"The January wood, after forty-eight hours, passed a few drops; during the same time the entire quantity had run through the February wood; and the water had passed through the March wood in two hours and a half. This accounts for the fact that barrels, of which the wood was felled in February or March, will lose within a year as much as 8 quarts of water, whilst others lose hardly any at all. One should suppose that wood would absorb salt water more easily than fresh water, because of the pressure of the former being so much higher; still, this is not the case; and Mr. Duhamel has proved this by an experiment. He took two pieces of oak from the same plank, each weighing 5 pounds. During eleven months the one was exposed to sea water, and increased only by 2.141 lb. in weight, whilst the other put into fresh water increased by 4.141 lb. in weight.

"Wood which lies in the atmosphere will constantly vary in weight, which depends upon the wet or dry season, and as the action is accordingly, we find the wood in its section, in a regular hygrometrical action.

"If we attempt to abstract all moisture by heat from the wood, we must not forget that at the same time we destroy its nature; that is, the physical condition of the wood, by which it becomes very liable to break. Too much hot oil on wood has almost the same influence; by this it loses considerably in weight; and soon after the oil has been put on, the wood becomes brittle, and *warps* more easily than in its natural state.

"The remainder of the sap, which is left in the pores of the timber, serves as a binding substance in the whole. It also prevents hygroscopical action provided the tree was cut at the proper time. The hygroscopicity is in constant action in the wood, and affects its body, shape, and weight, which in time leads to its dissolution.

"This change is as much a chemical as a physical process, and is noticed in all woods. The weight of wood is of great importance to us because its hardness, resistance, and its heating power, as well as other valuable properties, are all more or less depending upon it. Let us, therefore, enter closer into this subject. In the first instance, we must consider that even wood which has been forested very light will become heavy when put for some time into water; but in such timbers the sap is already given to dissolution. If the fibre were the only substance in the wood, then the specific weight would depend upon the number of pores contained in its body: the pores are, however, filled with a substance such as rosin, die, &c. It comes to this: that young trees contain a great quantity of sap, whilst old trees have in the same proportion less; a volume of air being contained instead.

"Suppose we leave the troublesome portion (the water) out of the question for a moment, and inquire into the reason which causes the heavier or lighter specific weight in dry wood.

"The hardest and heaviest woods come from the hotter climates: the only exception is the pine, which thrives considerably better and furnishes heavier timber when it has grown in colder regions or upon high mountains.

"Trees grown on northern slopes furnish lighter timber than if grown on southern or western. In these remarks we have already noticed the fact that the soil has great influence upon the width of the yearly rings; and I also remarked that from this we are able to come to a conclusion in regard to the specific weight. We have since heard of a number of facts by which the connexion between the yearly rings and the specific weight is greatly modified; but, as an instance, I mention the fir and larch trees, which both are heaviest when their rings are smallest.

"Another influence upon the specific weight is exercised by the resin and the die which are contained in the interior of the

wood. On level dry ground or deep sandy soil we find the fir (*Pinus sylvestris*) beautifully red inside; in the same condition we find the leg-fir (*Pinus muglius*) on turf soil where there is an abundance of water; but when we look at it on lias soil, it shows broad yearly rings and hardly any colour at all. The larch tree, again, in such soil develops itself well, with a rich colour. The cause for these appearances must therefore rest with the chemical condition of the soil and its effect upon the individuality of the fir. Oaks generally furnish good timber when grown slowly in dry ground, whilst those from wet soil appear comparatively spongy: similar results are obtained with other trees.

"Trees cut in summer give lighter wood than when felled during winter time. The cause for this may probably be ascribed to the fact that in winter a large amount of nourishment is stored in the stem which, during the spring and summer, is spent for the formation of bloom and leaves.

"We call hardness of the wood resistance which it opposes when another body enters it. If wood were an equal body like minerals, we should be able to determine its resisting power or hardness; but it being differently built, and, whilst trying its hardness, other properties interfering, we cannot arrive at a decisive result.

"Sometimes a wood has very hard fibres but very little body; that is, it is lighter built than another wood with soft fibres and a full body: it is therefore unadvisable to judge the hardness of a wood according to its fibres. Experiments to ascertain its hardness should be made across the stem and not upon a longitudinal section; and although there is no instrument which leads us at once to a definite result, we can generally arrive with a saw at a fair conclusion. Many persons constantly employed on wood are of the opinion that it becomes harder if it is worked or barked whilst green.

"Wood, as a porous body, contains in its natural state—whether dead or alive—a certain amount of moisture: by the loss of that moisture or increase of the same the bulk of the wood either contracts or expands.

"If we have a piece of wood when this action takes place only upon one side, it is obvious that the piece will alter its form or shape.

"The consequence of the loss of moisture is also the warping and splitting of the wood. The inner structure of a stem is irregular: for instance, we find the inner moisture of a yearly ring to be more than on its outer side: this causes the splits on the exterior, after the wood is dry; and it also accounts for the impossibility to form out of green wood a regular body which could not lose its weight or shape. The time during which the evaporation of the moisture takes place depends upon the state of the atmosphere. Several authors are of opinion that the contraction is regulated by the specific weight. This, as a rule, cannot be adopted: for instance, lilac and oak both being heavy and hard, contract quickly, whilst the double American maple, which is equally hard, contracts slowly. It is evident, however, that the fuller of sap a tree is the greater will be the contraction. This will account for the fact, that we find on cut timber the cracks extend from the exterior towards the centre, because the sapwood will contract more than the heart-wood.

"Planks turn with their sides upwards; that is, the edges rise from the level of the centre line. This explains why we turn the inside of a plank towards the joists whilst we lay a floor, which prevents the twisting. The contraction and action of the wood cannot be checked altogether. Among the means to prevent it stands foremost the one of putting the tree into water; but when taken out it must not be stored in a place where it dries too soon, as it still would burst if done; nor must it be left too long in the water, as this will injure the quality of the wood.

"All the wood which is used is never quite dry: besides this, it works a little in itself under the changes of the atmosphere; and therefore attention must be paid to the selection of the timber for the same purpose, for the heart-wood is less subject to such action than sap or splint wood. This is an important point with the furniture makers. The expansion or contraction is less apparent in the length of the fibre than in the cross section of the wood.

"The elasticity of the wood is called its property of return to its original form and shape after such have been altered by another cause. With this quality is connected the valuable fitness of some woods to transmit sounds, for which reason they are *much used by instrument makers*. The elasticity has its limit;

and the more a piece of wood can be bent without breaking the greater its elasticity.

"The resistance of wood depends upon the three following conditions:—1st. Two pieces of equal length and height offer different resistance with reference to their breadth. 2d. Two pieces of equal length and breadth offer different resistance with regard to their height. 3d. Two pieces of wood of equal height and breadth offer different resistance with regard to their length.

"Again, experience has proved that a piece of wood resting freely with its two ends will carry from one-third to one-half less weight than if the ends are fixed or built in a wall. Old wood has less elasticity than young, and heart-wood is less elastic than sap-wood. The same difference is found with wood from the lower stem compared with that from the upper crown. The elasticity diminishes with the progress of the specific dry weight. Square-cut timbers laid horizontally with their yearly rings have not by far such bearing power as when laid perpendicularly.

"Green wood has considerable elasticity. Young stems, although they suffer sometimes by the wind, will regain their original position in a short time. Here it is necessary to mention that where young stems or branches have been bent through snow for a longer period, they will not return to their former form.

"I submit to you the following as the result of some experiments relative to the bearing capacity of various woods. The pieces were all three feet long and 2 inches by 1 inch, and air-dry. The constants arrived at were the following:—

	Constant.	Wet.	Weight per C. ft.
Yellow Pine	358.5	...	25.687 lb.
Baltic Pine	444.	...	29.062 "
Red Pine	467.	...	33.437 "
Ash	517.75	53.875	41.812 "
English Elm	595.25	...	37.312 "
Pitch Pine	629.	...	45.750 "
American Elm	631.5	...	45.312 "
American Oak	653.5	...	44.875 "
African Teak	673.5	...	60.562 "
Mora	691.	...	71.250 "
Sabicu	854.25	...	59.687 "
African Oak	869.5	...	...
Greenheart	1,079.5	...	69.750 "
English Oak	—	...	53.312 "
Indian Teak	—	...	38.125 "

Iron Wood	—	...	73·500 „
English Larch	—	...	32·562 „

“Formula to find the breaking-weight of a piece of timber:—
c constant, *b* breadth in inches, *d* depth in inches, *l* length in feet, *w* breaking-weight in pounds.

$$\frac{c \ b \ d^2}{l} = w.$$

“The adaptability of greenheart for hydraulic construction, dock-gates, &c., cannot be over-estimated. I refer you to an instance where a clough was taken out of a sewer after sixteen years: it had been made half of oak and the other half of greenheart: the oak was completely worm-eaten, whilst the greenheart was in its original condition. This certainly contrasts with the fact mentioned by Mr. Burnell in his paper, that he has a piece of greenheart riddled by the teredo; and it would be interesting to ascertain under what circumstances the teredo will attack or not attack this kind of wood. My experience proves that greenheart is exempt from the therosion by the teredo; but there is a mollusc in this timber which we find alive in it as the same arrives here from the West Indies. The worm is found in sizes from the lymexylon to the teredo; but is of a different species, and seems not to live in this wood when used in such constructions as dock-gates, &c., in this country. Green sapwood will not retain its form and bend if it is suspended horizontally by its two ends.

“The same will occur in timber constructions where green wood has been used. I may mention that the artificial process of drying wood should not be extended beyond 10 per cent., because it will cause it to become brittle and totally useless. A close examination of a beam supported by its two ends will tell that the upper half of the fibres are stowing while the lower fibres are extending. The centre of gravity lies in the middle of the cross section. All woods do not offer the same resistance, and we can increase it by strengthening the centre of gravity. M. Duhamel describes in his work, ‘De la Force des Bois,’ the following experiment in elucidation of this fact: he took twenty-four sticks cut from young willows of equal strength: each stick was 3 feet (Paris) long, and $1\frac{1}{2}$ inch square. Six of these broke in the centre, with an average weight of 256·909 kilogrammes (1 kilo-

gramme equals 2·205 lb. English). In two other pieces he made a cut across $\frac{1}{2}$ inch deep in the centre, and filled it out with a piece of oak : they broke with an average weight of 269·718 kilogrammes. Two more were cut $\frac{1}{2}$ inch deep, and otherwise treated in the same manner : they broke with 265·312 kilogrammes. Five were cut $\frac{3}{4}$ inch, and broke with 259·764 kilogrammes. From this it results that the smaller piece of harder wood, fixed across the centre, considerably increased the strength of the stems when put in half and even three-quarters of the thickness. It is also the reason why a beam composed of several smaller pieces will bear as much as if of one entire piece. And again, as the bearing power of the timber varies, some advantageous results may be obtained by putting stronger and weaker wood together in a construction.

"A round or square piece of a stem will offer about the same resistance from each side ; but if we compare a timber cut with the yearly rings vertically with another having the rings horizontally, we find that the former will bear more than the latter.

"The sap which protects the wood does not prevent its decay. Turpentine, which is often in the sap, prolongs the preservation of the fibre. According to Baron Liebig, the decay of wood takes place in the three following modes : first, oxygen in the atmosphere combines with the hydrogen of the fibre, and the oxygen unites with the portion of carbon of the fibre, and evaporates as carbonic acid. This process is called decomposition. Secondly, we have to notice the actual decay of wood which takes place when it is brought in contact with rotting substances ; and the third process is called putrefaction. This is stated by Liebig to arise from the inner decomposition of the wood in itself ; it loses its carbon, forms carbonic acid gas, and the fibre, under the influence of the latter, is changed into white dust.

"As an example of this, I refer you to the wooden ceilings of houses which after some time go into that state. The chief cause is, that the free access of the air to the wood is prevented, and the little dampness occasioned by washing is sufficient to promote the dry rot.

"The sap of wood contains partly saccharine matter, which will naturally decompose in itself, and this is noticed in timber stores from the sour taste and smell of such woods.

"The actual time which wood lasts depends in a great measure on the time when it was felled, and in how far the soil in which it grew was suitable for its development.

"As a rule, the wood cut in summer is less durable than that felled during the winter months.

"It will also be the case with trees which remain a longer period before their removal in the forest after being cut; however, a great difference does not exist between ripe woods, whether they are felled in the summer or winter time, because the formation of the leaves and the blossoms affects only the sap wood and the bark of the tree; therefore, if the sap wood is cut off and the heartwood is properly treated and seasoned, the quality of the summer wood would be equal to that cut in winter time. In support of this I mention, that most of the trees in Southern Italy are felled in July and August.

"The pines in the German forests are cut down mostly in summer time, and their wood is generally very sound. The notion that this causes dry-rot must remain out of the question, for I believe whenever such takes place it is in consequence of unseasoned timber being used. Considering the large quantity of timber imported into this country, I must mention that my experience tends to show that the North American woods, with the exception of red pine, are less durable than those from the north of Europe. The latter are stronger, superior, and not so much subjected to dry-rot as the former.

"In the earlier portion of this paper I had occasion to mention some enemies of the wood which attack it whilst growing: it is lucky that they are combated and destroyed to a great extent by other animals in the forest; and, among those doing great service in this respect let us remember the woodpeckers, finches, swine, hedgehogs, badgers, frogs, and many others.

"Dry or dead wood has also some terrible foes, which at times cause alarming ravages; and unfortunately no effectual means have as yet been found to check them: the most dangerous of them are the termites, the *lymexylon*, the *sirex gigas*, the *teredo*, and the *lymnoria terebrans*.

"It is sometimes difficult to distinguish good from bad timber, and I beg to draw your notice to some illustrations from a work published by the French Government,—*Instructions sur les Bois*

de Marine,' with special reference to the oaks, and to which the following explanation may serve :—

"Plate 43, figure 1,* represents meagre or better known as English oak, of the best quality. To this kind of oak belong the *Quercus pedunculata*, and the *Quercus sessiliflora*. The fresh cut of such is a yellow straw colour, sometimes of a rose colour. The annual rings show a fine glossy grain, which allows it to take a fine polish. The horny layer of three to five millimetres is quite distinct from the cellular portion, and the pores are very little to be seen.

This kind of oak is very sensible to the influence of the atmosphere. In damp weather it swells, and in a dry temperature it contracts considerably. This makes it liable to split ; but notwithstanding this it is excellent wood, and the best suited for the ribs in a ship. The fibres hold together with a great longitudinal and even transversal tenacity, which gives it a great resisting power.

"Plate 43, figure 3, (see foot note), shows the cross section of an inferior quality. It is spongy ; has large pores of a pale colour, sometimes brown or reddish ; its deficiency has been caused by too wet a soil, by want of nourishment, or of fresh air, or of any other condition requisite for its full development.

"If such wood be ruptured it will break clean off, and a fibre may be rubbed into dust between two fingers. A valuable property of this kind of oak is, that it alters very little by the changes in the atmosphere, and it is therefore much in use for floors, furniture, and carpentry.

"Between these two qualities of oak, range a great number of others, differing in their condition.

"When trees are found to be vicious at the trunk, it must be attributed to an interruption of the functions of the roots. It will occur that one or several of the roots die, by which putrefaction is imparted into the lower part of the stem. If this rot be white or black, it is not very dangerous : it does not generally reach more than 1 foot above the roots ; but when this rot is of red colour, the wood should not be used in construction, or it will soon lead to decay.

"Trees arrive at an age when their wood becomes ripe, and

* Not given here. See No. of 'Builder' for Feb. 28th, 1863.

then it is time to fell them. It may be seen when the top of the tree brings forth no leaves in spring. Such trees are superannuated; that is to say, they grow no longer; and then they become subjected to a serious evil called the dial. This is explained by the following process:—We know that with a vigorous tree in full growth the heartwood contains the smallest portion of water, and that its density decreases from the centre towards the circumference: when it is felled and dried it will split from the outer side towards the centre. This is not the case with a superannuated tree, in which the oldest wood begins to perish first; and consequently the greatest density lies between the heartwood and the bark. Now, in such a tree the central wood contracts while drying, which causes the splits. Sometimes splits are found in trees which bear a glossy blackish aspect, and they must be distinguished from those just mentioned. They extend from the circumference towards the heart, and were created whilst the tree was growing. It is asserted that they are effected by frost. They look at first straight or capillary, and enlarge with each heavy cold. They show themselves mostly longitudinally, on a swelling of the stem, and make the tree useless.

“The splits in the heart of a tree must not be confounded with holes caused in falling. There is no danger with the latter beyond that they diminish the length of the timber.

“Often in the trunk of a stem a particular irregularity is found in the non-juxtaposition of two successive annual rings.

“This fault is caused by strong winds, which affect it in the point where the flexion of the stem has its maximum.

“It will also arise when the tree has not sufficient nourishment, by which two layers are prevented from growing well together. It shows itself in incomplete dark rings. If these are only in the sapwood they may be looked upon as unimportant; but when they are, on the contrary, in the heartwood, and accompanied with the dial, they betray a serious vice in the tree.

“In different cross sections of an oak we often notice circular bands of a different colour from the remainder of the section, sometimes white, yellow, red, or brown. The texture of these bands appears loose, even spongy, and betrays signs of decomposition. It is found in the best qualities of wood, and it can-

not be cured. The reason for this decay is not definitely known. Some persons suppose it to arise when the sapwood is prevented by severe cold from developing itself into good wood. When this evil is in the heart, it looks like a whitish circle, and is called the moon. Wood from such trees ought not to be used, because it will soon decay. When the vicious bands are straight, and the shades of colour are less observed, the vice is not so dangerous.

"Druxy knots are caused by woodpeckers, by lopping, and by dead and broken branches, which make holes into the tree: into these the water runs, decomposes, and directs the evil towards the inner stem. If we find on a tree a swelling or depression, we may conclude that the condition of the tree is bad. Such trees are often found with the sap running out of their armpits. Among the various rots engendered by the knots we have the following:—

"Wet rots are composed of porous fibre running from the knot into the trunk of a tree. This rot is of brown colour, and has an offensive smell.

"This evil is often found with white spots, the latter of watery substance. When it has yellow flames it is very dangerous. Black coloured knots are easily cured, and unimportant.

"We find wounds on trees which have been effected by the fall of a neighbouring tree or by the friction of a cartwheel through which the rind was torn. If this wound does not reach beyond the bark, it has no bad effect upon the wood; but should it have damaged the ligneous portion of the stem, the wood takes soon a green-like colour, and begins to decompose.

"It occurs that a new rind grows over such wounds, and in such instances the evil is not detected until the stem is cut into timber. Similar defects are also caused by lightning.

"As a very elaborate work upon the various kinds of oak, I mention Kotschy's, *Eichen Europa's, Durability and Preservation of Wood*.

"Well-seasoned timber will last for an indefinite period if kept in dry air or under water; but when alternately exposed to atmosphere, water, and light, it begins to decompose. The ordinary causes by which this is effected are chiefly the fermentation of the azotic substances contained in the cellular tissue.

This is developed under the influence of the oxygen in the atmosphere, and by the moisture contained in the wood. We have therefore the problem to find means to prevent this fermentation, either by obviating all such circumstances as air and water, or to extract from the wood its vegetal albumen, or to act upon the latter in a manner that it resists fermentation, and also the attack of insects. No process has as yet been invented which answers to all these conditions, and with all trials we must have the assistance of chemistry and entomology.

"I refer to our museums as the place where, among other rude-made articles, here and there is left a remnant of wood which bears the ages of decenniums, and other specimens of petrified wood which must have been in existence in its natural state centuries ago.

"That wood in sandy soil will last for centuries may be seen in the specimens which were dug up whilst making the new docks at Birkenhead, from depths varying from 8 feet to 32 feet below the surface, and they are reckoned to have been there for centuries.

"Among the many inventions to preserve wood, those of England have proved the most successful. Already in 1737 a patent was granted to Mr. Emerson, to prepare timber with hot oil, and soon after the methods of Oxford and Kyan came into use.

"In 1837 a patent was taken out by Margary, to impregnate wood with sulphate of copper; and since 1838, Sir William Burnett's system, chloride of zinc, was also used.

"Mr. Payne obtained a patent in 1841 for preparing wood with two solutions, such as carbonate of soda and sulphate of iron. Some very good results are obtained with this system, but it must be done with the greatest care.

"Still better is the invention patented by Mr. J. Bethell, which consists in the injection of oil of tar after the air has been extracted. This process is effective to a great extent, and for a full description I refer you to Mr. Brunell's paper, read before the Society of Arts, in London, 1860.

"The disadvantage with the creosoting system is the offensive smell and the increased danger by fire; but it is recommendable for railways and hydraulic works.

"In France the price of creosote is too high to admit its general use; and solutions of metallic salts are used instead. Among these M. Boucherie's method has obtained the best results. He acts with a pressure of 5 or 7 feet of water upon wood not later than two or three months after it is felled, and injects a solution of sulphate of copper by a transversal section, while the sap runs out in the opposite direction. Railway sleepers prepared in this manner were laid down in 1846; and in 1853 they were in such good condition that ever since M. Boucherie's system is much applied in France. Another economical process of Mr. Fontenay is worth mentioning. He acts upon wood with what he calls metallic soap, which he obtains from the residues in greasing-boxes of carriages; also from the acid remains of oil, suet, iron and brass dust, which are all melted together.

"A piece of wood was put in such a hot fluid for forty-eight hours after the water had previously been partly extracted under the ordinary pressure of the atmosphere. When taken out the metallic solution which it had taken up stood at 3 per cent. to its first weight. This piece of wood was used as a railway sleeper on the Orleans Railroad, and after eight months it was in perfect condition, whilst other wood not treated in similar manner was in a state of decomposition.

"Another process is the following, recommended by Mr. Dondeine, and much applied in France and Germany. It is a paint, consisting of the following:—

Linseed oil	15 kilogrammes.
Resin	15 "
Tar	5 "
Zinc or white lead	12 "
Vermillion, red or yellow	10 "
Colour (clay colours must be avoided as they thicken too much)	4 "
Cement	6 "
Oxide of iron	8 "
Gutta percha, glue, or gum	2 "
Hydrate of chalk	6 "
Lard	15 "
Litharge	2 "

(One kilogramme = 2.205 lb. English).

^o
ta, these are well mixed, and reduced by boiling to one-tenth.

When applied warm it may be used with a brush; but not too hot. It may also be used cold; in which case the paste must be mixed with a little varnish or turpentine oil. The results obtained with this process are reported as yet very satisfactory. It prevents decay, and admits no humidity.

“Mr. Dondeine further reports that it prevents oxydation of iron; and wherever walls have had a coat of this mixture it has kept away all wet, and unpleasant insects, ants, bugs, &c. Roofs of pasteboard or of wood which have been painted with the mixture keep dry, and withstand the effects of rain and snow.

“Wood impregnated with sulphate of copper will not last longer in sea-water than other wood. It is quite as much attacked by the sea worm as when in its natural state. On the other hand it has been proved that wood impregnated with sulphate of copper, will have longer durability in the soil than when either tarred or charred.

“The following statement of M. Brouzet to the French Academy may also be of interest. He has a seat in the Carennes Mountain, where he cultivates silk-worms. The shelves upon which they breed are of pine. During the period from 1853 to 1858 all his crops perished through illness. In 1860 he was induced to make new shelves of pine impregnated with sulphate of copper, and ever since the silk worms have been in the finest and healthiest condition. (See ‘Comptes rendus de l’Academie Française,’ vol. 54).

“At Saint Sebastian, in Spain, the piles of a wooden bridge standing in the sea have been guarded against the attacks of sea-worms in the following manner. Each pile is surrounded by a wooden box, and the space between filled up with cement. After six years it was proved that the piles were in perfect condition, whilst the outer boxes were completely riddled by the worms.

“With these I conclude the remarks on wood, and will next consider some works which have been constructed in that material.”

On the *Growth of trees* the following is a note addressed to the Editor of the ‘*Engineer*,’ by William Burns, C.E. :—

“The following article on the growth of trees has appeared in several periodicals lately, but while the article shows the popular error it does not explain the cause of the want of uniformity in

the thickness of the annular rings of trees. Will you allow me, therefore, to append a few facts which might be of some value to a number of your readers:—

“‘POPULAR ERROR REGARDING THE WANT OF UNIFORMITY IN THE THICKNESS OF THE ANNULAR RINGS OF TREES.—On reference to the cross section of a newly felled tree, it will be observed that the timber has not formed of uniform thickness round the pith of the tree. This is uniformly the case towards the base of the spruce, Scotch fir, and larch. The popular belief is, that the wood forms faster towards the side most exposed to the light and the heat of the sun’s rays. Were this the case it would prove that we have more of these from the south-east than from any other quarter. The prevailing high winds in Britain are from the north-west or south-west, and they usually blow hardest in autumn, when the young wood is most liable to be permanently bent in any given direction. This makes the top lean towards the north-east or south-east; and, by one of the many admirable compensating operations of the Great Creator, the wood at the base grows fastest on those sides, so that it may act as a natural buttress, and maintain the centre of gravity.’”

“The above is a very old-fashioned, but very unsatisfactory, method of trying to explain the cause of any effect we do not understand; in fact, it is no explanation whatever. We know that the Great Creator is the first cause of every operation in nature, but he at the same time causes secondary laws to govern many of the operations of nature; and if we examine the powers operating upon the growth of trees, we will find that it is by simple mechanical action that the annular rings are always thickest on the side opposite to the direction of the prevailing winds, because, when the tree is bent, it forms a bow or arch, and the fibres on the convex side of the arch undergo a tensile strain, which partially closes the pores of the wood on that side; while, on the concave side of the tree, the fibres undergo vertical compression, which has a tendency to open the pores on that side; consequently the sap rises more freely on the concave side, and causes a more rapid growth on that side than on the other; at the same time the wood is much softer than on the convex side. *In proof of this, take the Scotch fir, larch, or spruce, and examine the cross section near the base with a microscope, and it will be*

found that the pores on the convex side are much finer and compact than on the other.

"Again, take a longitudinal section of the tree cut through the centre so as to show both the convex and concave sides, and it will be found that on the convex sides the fibres are hard and run in nearly straight lines, whereas on the concave side they are soft and have a wavy appearance caused by vertical compression. Again, cut equal portions from the convex and concave sides of the same tree opposite one another, and dry them thoroughly, and it will be found that the wood from the convex side has a much higher specific gravity than that from the concave side. Again, the wood cut from the convex side is much stronger and will sustain a greater transverse strain than wood cut from the concave side of the same tree. Again, the wood cut from the convex side of the tree is more durable than that from the concave side. Where Scotch fir, larch, or spruce has been used for roofing, joisting, or flooring, I have always found that the concave side, with the larger fibre, gets worm-eaten and quite rotten long before the other side. These facts I discovered many years ago; a knowledge of which is invaluable to parties using that kind of timber to enable them to know in what direction to cut up the trees for certain purposes."

On the *Preservation of timber from decay* the following facts from the '*Builder*' will be found useful:—

"From reliable experiments that have been made in Europe and the East Indies with railway sleepers which had been treated with pyroligneous acid, it has been demonstrated (says an American paper) that they endure three times longer than the same kind of timber, not so prepared, when exposed to similar influences. Many improvements that have originated in America have been first applied in other countries. This has been the case with respect to the treatment of timber with pyroligneous acid. Its application for such purposes was proposed in New York forty years ago, but it has not yet come into general use there, while it is in very common use in England. In the New York '*Daily Advertiser*,' of Dec. 24, 1823, a description was given of experiments that had been made in treating timber with pyroligneous acid, and its benefits and modes of application were clearly described. No railroads were then in existence; conse-

quently, its use was chiefly urged for ship timber exposed to rapid decay. The article on the subject said:—‘When seasoned timber or planks are hewn into the intended shape, put them under cover for a week or ten days to protect them from the rain. During this time let the acid be applied to the surface daily with a brush. It will penetrate an inch or more into the wood, and will be found an effectual preservative. The central part of the wood or heart of the oak being less liable to decomposition, it will require less of the acid. The frame of the ship or boat may be put together when all the external parts of the timber are completely saturated. Green timber cut in thick forests after being saturated with this acid will be nearly as good for ships, steam and canal boats, as the teak wood of the East Indies or the live oak of our sea-coasts.’

“The pyroligneous acid recommended for this purpose was the condensed smoke of wood. The best way to obtain it is by the distillation of wood in an iron retort and the condensation of its vapour in a refrigerator. The charcoal thus obtained in a retort is of excellent quality for smelting iron, and the crude pyroligneous acid may be applied without any further treatment to the timber. It was not only recommended for ships’ timber to prevent dry-rot, but also for the timber of gun carriages, posts set in the ground, the sills of wooden buildings, &c. By smoking timber in the same manner that hams are smoked, similar results are obtained, for the preservative agent is the creosote in the fluid and the smoke. In coal tar there is a similar preservative agent called carbolic acid, which in many of its properties resembles creosote. It answers the same purposes as an antiseptic for timber, and is used for this object, but it is disagreeable to apply; wherever it can be obtained conveniently, however, no better substance can be applied to timber intended to be exposed to moisture and the weather, more especially when in contact with the ground.”

From the ‘*Builder*’ we also take the following on the use of *petroleum for preserving wood*:—

“The oil wells near Prome, in Burmah, have been in use from time immemorial. Wood, both for ship-building and house-building, is invariably saturated or coated with the product of those wells. The result is entire immunity from decay, and the

ravages of the white ants which in that country are so generally destructive. M. Crepin, a Belgian Government engineer, who has tried experiments on the relative advantages of creosote and sulphate of copper for the preservation of timber in marine constructions from the attacks of worms, &c., says that creosoting is the only process he has found to succeed for this purpose. He states that sulphate of copper affords no protection whatever against the action of salt water and marine insects. The Belgian Government now require that all the wood sleepers used in the State railways should be creosoted; and the Government of Holland have also made the same resolution; and upwards of 300,000 sleepers per annum are now being creosoted by the Dutch Government, and more by the Belgian Government."

A correspondent, "A. T." (Antwerp), writes to the '*Builder*' on *Wood Preservative Processes abroad*:—

"I have read with much interest the article in your journal entitled 'Notes on the Properties of Wood.' Noticing the importance you attach to the different processes for preserving wood, I make so bold as to offer you some data which have been arrived at in Belgium, Holland, and France, concerning their relative merits. It is quite true, as you say, that the continental engineers esteem the processes of English origin the most highly, and especially Mr. Bethell's creosoting process. The efficacy of the creosoting process has for some years been admitted in the most absolute manner by the engineers in the Netherlands, and no other wood-preserving process is used by them. It has been proved in an equally absolute manner in Belgium by a series of experiments upon the principal wood-preserving processes, made by the Belgian Government engineers. These experiments have lasted through a period of twelve years, and were conducted with the greatest care and vigilance. In the course of these experiments there were laid down creosoted sleepers, 223,654; sleepers prepared with sulphate of copper, 199,061; sleepers prepared by other processes, 25,730. And in 1860, 'Compte Rendu des Opérations des Chemins de Fer Belges, 1860,' page 28, the Minister of Public Works published his determination to prepare in future all railway sleepers with creosote, except the oak sleepers, which are not to be prepared at all. M. Crepin, a Belgian Government engineer, who has tried experiments upon the

relative advantages of creosote and sulphate of copper for the preservation of timber in marine constructions from the attacks of worms, &c., has lately published a report; 'Annales des Travaux Publics de Belgique,' tome 19, in which he states that creosoting is the only process he has found to succeed for this purpose. Indeed, he states that sulphate of copper affords no protection whatever against the action of salt water and marine insects.

"As regards France, I must add that although immense quantities of timber prepared with sulphate of copper have been used by the French railways; nevertheless, there also, experience points to the condemnation of this preservative. At the end of the last year, the committee of the Belgian engineers being unable to reconcile the facts they had observed in Belgium with the opinions of the French railway engineers, and fearing lest the failure of sulphate of copper in their experiments had been occasioned by some imperfection in their mode of employing it, the Belgian Minister of Public Works asked permission from the Nord and other railways of France for a committee of Belgian Government engineers to inspect the sleepers prepared with sulphate of copper and placed on the said railways in France. The result of the inspection made by the committee proved to them that no better results had been obtained in France than they had obtained in Belgium; and that consequently they had not to blame themselves for any want of skill in their application of the sulphate of copper process. It was quite by chance, through my being in London for a few days, that I came to read your article; and it is in the interest of truth alone that I send you the above facts, which I hope you will kindly place in your next number.

"The Belgian Government now require that all the wood sleepers used in the state railways should be creosoted; and the Government of Holland have also made the same resolution; and upwards of 300,000 sleepers per annum are now being creosoted for the Dutch Government, and more by the Belgian Government.

"A. T., ANTWERP."

M. Lapparent, director of one of the French dockyards and inspector of timber, in presenting a report to the Government on the preservation of timber, states, among other things, that "the

sap of timber is composed of nitrogenous elements which are called *unstable*, because under certain circumstances they are so liable to change—producing rot. When timber is treated so as to alter the nature of the sap or to dry it completely by what is called *seasoning*, it resists decay more effectually than if used without being dried. Moisture and confined air tend to produce decay in timber, and on the other hand timber exposed to a free circulation of air and shielded from moisture will retain its strength almost unimpaired for centuries. The oak beams, rafters and other timbers of old churches and houses which were built before the plastering of walls was introduced, have remained sound for six and seven hundred years. Of course, ships cannot be kept dry, but if their timbers are well seasoned before they are exposed to the elements, it has been found by experience at the French naval dockyards that they will endure five times longer than timbers not thoroughly seasoned.

“It is well known that when timber is steeped for a certain period in water, then exposed to the air to dry, it seasons more rapidly. It has been customary, therefore, to immerse ship timber in water prior to drying it. On this head M. Lapparent states that the practice of those shipbuilders who steep their timbers in sea water is wrong, and that fresh water is the most suitable for this purpose. For oak planking, he states, it should be steeped one year in river water, two years in fresh water not so frequently changed; while in brackish water, continually changing, it requires three years’ immersion.

“In drying timber to season it, exposure to the air is the most simple method, but this requires a very long period of time for large ship-timber. Another method consists in drying it in large rooms exposed to currents of hot air driven in by fans. By this system the surface of the timber is liable to become dry and crack before the interior is seasoned, and for planking it is, therefore, objectionable. Another method has lately been tried near Cherburgh, France, which consists in exposing it to the smoke, steam and gas of wood and coal under combustion. The small amount of moisture in the smoke prevents the timber from cracking, and M. Lapparent looks upon this mode with favour. But his favourite method in treating timber to prevent its decay is *the charring of its surface*. He states that this plan was once

tried during the last century in the British royal dockyards; that the frigate *Royal William* was built of carbonized timber, and that it was one of the most remarkable cases of durability on record. This system has been revived in France with improved apparatus, and it is about to be extended to all the dockyards in the empire. The timber to be operated upon is secured upon an adjustable table and its surface is slightly charred by a flame of gas mingled with a jet of air. The consumption of gas is 200 gallons for 10 square feet of carbonized surface, and one man can carbonize 440 square feet in ten hours. Some timber is improved by giving its surface a very thin coat of tar before it is charred. It is stated that the whole surface of timber is carbonized with great uniformity by this method, and M. Lapparent says:—"It ought to be applied to every surface in contact with, or in general intended to be surrounded by, moist and stagnant air." It is also recommended for treating the beams and joints of house timber, intended to be embedded in the walls or surrounded with plaster. By carbonization a practical and economical means is also offered to railway companies of preserving, almost for ever, their sleepers, particularly those of oak. In France, the annual cost for vine props amounts to no less than 24,000,000 dols. By charring these this cost will be reduced two-thirds, and a relative saving will also be effected in thus treating hop poles. As the vine and the hop are extensively cultivated in America, this system also deserves the attention of our people who raise these agricultural products.

"In building ships M. Lapparent suggests that horizontal holes should be bored through the ribs, at certain distances apart, and there should be spaces between the outer and inner planking to permit currents of air to be driven between the ribs, also that portions of the ribs should be smeared with a paint composed of flowers of sulphur, 200 parts; linseed oil, 135 parts; and manganese, 30 parts, to prevent the development of fungi. In conclusion M. Lapparent says:—"I have pointed out the means for preventing the rapid decay of timber; they are simple, logical, economical, easy of adoption and perfectly innocuous. By employing them we shall save that timber for building ships which is, in my opinion, far superior to iron, for the same purpose."

DIVISION NINTH.

GENERAL MACHINERY—INCLUDING AGRICULTURAL
IMPLEMENTS.

Wood-working Machinery.—"Should architects and builders ever consent," says an able writer in the '*Engineer*,' "to adopt standard sizes and patterns of doors, window frames, sashes, shutters, staircases, &c., a great field would be opened for the introduction of wood-working machinery. Mr. Whitworth, who has given so much attention to the proper graduation of size in all the various branches of the mechanic arts, observed, in an address delivered in 1856 to the Institution of Mechanical Engineers, 'I think no estimate can be formed of our national loss from the over multiplication of sizes. * * * This question is also well worthy the attention of our architects and builders. Suppose, for instance, that the principal windows and doors of our houses were made only of three or four different sizes. Then we should have a manufactory start up for making doors, without reference to any particular house or builder. They would be kept in stock, and made with the best machinery and contrivances for that particular branch; consequently we should have better doors and windows at the least possible cost.' In the construction of carriages, furniture, &c., a determination on the part of the leading makers to secure such a degree of uniformity as to permit of the more general use of machinery would result in a better quality and lessened cost of the articles produced, just as machinery has improved and greatly cheapened a large number of manufactures formerly carried on by handicraft. There is still more or less prejudice against machinery, and as for wood-working machines they now cost heavily, although there can be no question as to the excellence of their quality as turned out by our leading makers. As a rule our builders work rather harder and more costly woods and with less waste than the American wood-workers, but the differences in the prices of the tools employed are extraordinary. Let us take a rack circular saw bench. One, by a first-class firm, with a rack-bed 40 ft. long, 26 in. wide, and intended for a 62-in. saw, running at 600 revolutions, and cutting 27 in.

deep, weighs 8 tons, and costs, exclusive of saw, £260. Her-
rick's portable circular saw mill, used in the States, having a
60-in. saw, running at 400 revolutions, weighs $1\frac{1}{2}$ tons, and costs,
inclusive of saw, £100. Here we have a planing machine, with
both fixed knives and revolving cutters and side cutters, the whole
weight being six tons, and the maker's price £380. The Ame-
ricans use chiefly revolving cutters; and with these their Wood-
worth planing machines, with iron frames, 13 ft. long, planing
24 in. wide, and having top and bottom cutters and grooving
cutters, and made throughout in the best style known in the
States, cost £190. A class of machines on the same principle,
but having wooden frames, and designed for planing narrower
boards on but one side at a time, costs £110, and is largely used
in the States. Mr. Whitworth found them planing boards 18 ft.
long, and varying from 3 in. to 9 in. in width, at the rate of 50
ft. per minute. The cutter heads had three cutters, the circle
described by the cutting edges being 12 in. in diameter, and the
speed was 4,000 revolutions, or over 12,500 ft. per minute. Mr.
Whitworth was informed that the cutters only required sharpen-
ing with the oil-stone once for every 2,000 ft. to 3,000 ft. of
work, and grinding once for every 20,000 ft. to 30,000 ft. Our
best makers charge £200 for a planing, surfacing, and squaring-
up machine; and where made double, to take two pieces of tim-
ber 18 in. square, the price is £325. A machine for the same
purpose, and known in America as the 'Daniels planer,' planing
42 in. wide and 50 ft. long, costs £102; while that planing 16
in. wide and 20 ft. long costs but £42. The best power mor-
tising machines made in the States have also a boring spindle,
and the chisel is worked through a link in such manner that,
without interfering with the driving power, the stroke may be
instantly adjusted from $\frac{1}{8}$ in. to 1 ft. by the pressure of the foot
upon a treadle. These machines cost from £26 to £65. The
largest and best mortising machines made in London cost, with
boring apparatus, £200, the smaller machines costing from £80
to £100. Without extending the comparison we may say that
the prices of wood-working machines, such as are used through-
out the United States, vary from one-fourth to one-half those
*which prevail here for machines intended to turn out about the
same or possibly a rather larger quantity of work, although in*

some cases the American tools are made to turn out more work than ours. The American wood-working machines have generally had wooden frames, but this does not account for their cheapness, for where iron frames are adopted, the price of the machine is but very little more. The framing is, however, very much lighter than our own, the whole weight of the machine being always much less. The American machinists insist, however, that their wood-working machines are amply strong, and while they are doing probably a hundred-fold, if not a thousand-fold, more wood conversion than is done in all the rest of the world together, they could not be induced to adopt our proportions.

"While upon the subject of wood-working machines, it may be interesting to state the actual standard thickness of the circular saws used by the American sawyers. For from 4-in. to 5-in. saws, No. 19 of Stubs' gauge is the thickness employed, from 6 in. to 8 in. No. 18, 9 in. No. 17, 10 in. and 11 in. No. 16. Saws of from 14 in. to 16 in. are of No. 15 gauge, 18-in. saws No. 14, 20-in. No. 13, while from 22 in. to 26 in. the gauge is No. 12. Saws of 28 in. and 30 in. are of No. 11, and from 32 in. to 36 in. No. 10. From 38 in. to 42 in. No. 9 is adopted, while from 44 in. to 52 in. a gauge of No. 6 to No. 7 is used. From 54 in. to 58 in. the gauge is from 5 to 6, and for saws varying from 5 ft. to 6 ft. in diameter, a uniform gauge of No. 5 is adopted. These thicknesses are rather less than the Americans have been supposed to use, although it is the fact that they do occasionally run thicker saws, especially at the high speeds of from 12,000 ft. to 15,000 ft. per minute, which they often employ. A 5-ft. saw, which costs here £18, costs £36 in the States; a 4-ft. saw costs £7 10s. here, and £12 10s. there; a 3-ft. saw costs £4 in both countries, while saws under 3 ft. cost less in the States than here.

"It may be that the band saw is destined to be much more used than heretofore for heavy sawing. Mr. Worssam, we believe, has fitted it to some of his heaviest rack saw benches in conjunction with the circular saw, and for cutting logs up to 42 in. in diameter. For reciprocating saws a steam cylinder can be fitted directly to the swing frame, something on the plan patented last year by Mr. Greenwood, but with provision against the striking of the piston or swing frame, no matter how suddenly the

resistance to the saws might be removed. Thus the piston should have a trunk on its lower side, leaving an area upon which the pressure of the steam should be always sufficient to carry up the saws and frame, and upon this area the steam should be always pressing, no exhaust taking place, the area of the whole upper face of the piston being such that the steam should not only carry down the saws, but overcome, also, the constant pressure on the lower side. The cylinder could then be made of any desired length, without consequent waste by exhausting a large volume of steam from below at every stroke. A steam-moved valve, of the same form as the main trunked piston, and having a constant pressure of steam on its smaller area, might be easily fitted so as, without any valve gear, to regulate the admission and exhaust of steam to and from the top of the piston, and this could easily be arranged to give any required stroke to the latter, and that always without waste of steam. The cheapest and best reciprocating saw-mill which could possibly be devised might, we believe, be made on this plan.

"There is a useful tendency to combine upon the same frame two or more of such machines as are not required each to be in constant use. Thus Messrs. Worssam's 'general joiner,' on a single frame, and for £85, serves the purpose of, at least, five distinct machines, which, if constructed and sold separately, would cost from £300 to £400. This kind of combination can, doubtless, be carried out with advantage in the case of other machines.

"The rejection of needless weight, unnecessary finish, and roundabout combinations of parts and complicated movements, will lead to the production of a class of wood-working machines much better adapted to the general wants of engineers, manufacturers, and builders. American machines furnish, among others, one instance of such useful simplicity which we will notice, and which deserves to be copied. The journals being turned, they are placed in cast iron boxes, recessed out so as not to touch the finished surface by $\frac{1}{4}$ in. or so all round. Into this space is run a composition of 100 parts tin, 10 antimony, and 2 of copper, which forms a perfect wearing surface, and which may at any time be cheaply renewed. The composition lining is, of course, divided to serve both halves of the plummer box. Where lateral motion is especially to be guarded against, the journal is first

turned with a number of circular V grooves, each forming a collar like the thread of a screw, or like those in Mr. Robertson's frictional wheels, and the composition already described is then cast around the journal thus formed. This simple and inexpensive practice gives results not to be attained with fifty times the expenditure of money on other plans. This is but one illustration of the kind of improvement to which our wood-working machinery must be subjected before it can ever be used to anything like the extent of machinery for a like purpose abroad."

WHEEL-CUTTING MACHINES.

"It is scarcely necessary to urge upon any practical mechanic the great value of a good wheel-cutting machine. It is well-known that this description of special tool was amongst the first machines that made their appearance in English engineers' workshops. Messrs. Fox, of Derby, appear to have been the originators in England of an engineers' tool for cutting and dividing the teeth of wheels. Brass wheels, and wooden wheel patterns of a smaller diameter than six inches, and of fine pitches, have their rims generally cast to the depth of their teeth, which are divided and cut out of the casting by the machine. Circular, or rose-cutters, are often formed in the same way.

"If a cast-iron toothed wheel be cast perfectly true, it is, of course, better to leave it untrimmed. To take the skin off a casting always reduces its strength, but it also diminishes the duration of the teeth of a wheel. The skin on a casting is somewhat like the skin produced by case hardening a piece of wrought-iron. For many years Mr. Whitworth has turned out the change wheels of his lathes, &c., without any trimming. Larger wheels, however, are often trimmed up, as it is not so easy to cast a large toothed wheel quite true. The wooden cogs of mortice wheels are also generally shaped by hand, and this is more especially the case with the cogs of bevel gearing. Cast-iron wheels intended to work with mortice wheels, generally have their teeth trimmed up by hand. This is a costly and tedious operation, but its necessity is apparent. The wooden

cogs of a mortice wheel would be speedily worn away by the rough surface of cast-iron teeth.

"Steel circular cutters of the exact shape of the tooth are generally used for cutting spur wheels. It will be seen at once that it would be impossible to cut a bevel tooth by means of a circular cutter, without setting the cutter at an angle. The teeth of a bevel wheel of course advance and recede, both as to depth and breadth. Even when a correct circular cutter is used, the wheel is not completely finished by this process; it must be trimmed up by hand-filing. It is scarcely possible to get a correct bevel wheel by means of a circular cutter.

"In our number for October 24th, 1862, p. 253, under the heading of 'Machine-tool Substitutes for the File,' we alluded at some length to the subject of circular cutters, and we there proposed to make a circular cutter for iron upon the same plan as the cutters used in 'Biddell's patent oat-mills.' It is evident that the circular cutters used for wheel-cutting machines might be made in the same way. Circular cutters, formed of one piece of steel, often spring while being hardened, and are also very liable to warp while undergoing this latter operation. When in use, should any teeth be broken off, the whole cutter must be turned up, softened down, and recut. There is also a difficulty in sharpening the edges of the teeth, when the cutter gets worn. Mr. James Nasmyth, of Patricrift, some thirty years ago, made circular cutters out of a number of separate knives, in the following manner:—

"He built up the circular cutter out of a number of separate steel cutters, the inside of each cutter being of a wedge shape, and the whole number required were arranged in radii from the centre of the disc. A wrought-iron ring was shrunk on the circular bundle of cutters, so that it could be turned up in the lathe, just as if the cutter were in one solid piece. One side of the cutters is first turned up, and is then fitted into the chuck of the circular shaping or wheel-cutting machine. The chuck is furnished with a set-screw, and this screw is caused to press upon one of the separate cutters, which thus acts as a wedge between the other cutters. The wrought-iron ring is then knocked off, and the other part of the circular cutter is turned

up in the lathes, so that all the separate knives or cutters are of the same shape.

"On slackening the set screw, the separate knives can be easily taken out of the chuck, and filed up to the required shape. On being properly hardened, the knives are replaced in the chuck. They are then screwed up by the set screw, and the whole circular cutter is thus ready for use. Before the modern improvements in moulding, enabling us to cast wheels with greater precision, wheel-cutting and dividing machines seem to have been in greater demand than at present. We have seen, in an old German periodical for 1843, a design for forming a circular cutter for toothed wheels, upon a plan somewhat similar to that of Mr. Nasmyth. The German design was avowedly suggested by Mr. Nasmyth's cutter. A circular cutter for the teeth of wheels must, of course, cut on three sides, taking up the sides and bottoms of the teeth. This kind of circular cutter must also be fixed on a mandrel, and requires to take the shape of a wheel. It is thus impossible to fix such a cutter on the chuck of a lathe; it must be independent of all such support. The way described was the following:—The separate cutters were filed up to a wedge shape, and arranged in radii together; a wrought-iron ring being then shrunk on the whole. This steel disc was then placed on a lathe, and the centre bored out to the size of the spindle upon which it was to be fixed. The disc was then fixed on a mandrel, properly turned up to the required shape, and a circular groove was then formed some distance from the centre. This groove was made of a conical or bevelled shape, and a ring was fitted into this groove. The ring thus keeps the separate cutters together, when the outside ring was taken off. If this inside ring be once tightly driven into the groove, the outside ring can then be taken off. The steel disc or cutter is then placed on a mandrel, and turned up in a lathe to the required shape. There is a boss on the spindle of the circular cutter, and a nut is screwed up against the other side. The separate cutters are thus kept from being pressed out. These independent cutters can also be separately taken out, sharpened, and hardened, just like Mr. Nasmyth's cutters.

"In our volume for 1849 will be found a self-acting method, proposed by a student of St. John's, Cambridge, for cutting the

teeth of the drivers of pin wheels or trundles. We do not know whether this plan has ever been carried out.

"There were three machines in the International Exhibition for cutting the teeth of wheels; two of these used circular cutters. One was exhibited by Mr. Whitworth, of Manchester, and figured in the western annex. The second machine was sent by Cook and Sons; it was intended more especially for horological wheels, and was on the same general principle as Mr. Whitworth's machine. The machine exhibited in the International Exhibition by Mr. Whitworth, was intended to cut spur, bevel, and screw wheels; in metal or wood. It could cut wheels up to ten feet in diameter. This machine consisted of a long bed, similar to a lathe bed. A circular cutter was used, which was intended to be set at an angle when bevel wheels were required. The circular cutter was on a vertical spindle, working in an adjustable head-stock. The speed of this cutter could be varied to suit wood or metal. The wheel to be operated upon was fixed on the end of a mandrel fitted in a sliding bracket. There was an ordinary dividing apparatus for pitching the teeth. This machine is amongst the best tools of Mr. Whitworth. It no doubt does its work very efficiently, with respect to spur and screw wheels, but it is subject to the objections we have previously alluded to; when speaking of cutting out bevel wheels by means of a circular cutter. The third wheel-cutting machine was exhibited by John Hunt and Co., of Bow. We have also heard of this firm in connection with anti-friction metal bearings. It was a special tool for dividing and cutting bevel gearing. Although in an out of the way corner, it excited some attention, from its exquisite ingenuity, and as an example of right adaptation of means to an end. The attendant asserted that the machine could pitch and trim more wheels in one day than could be achieved in a week by a good millwright. The apparatus consists, essentially, of a shaping machine with a reciprocating tool. This tool has a stroke of about three inches. The slide is made upon the plan first adopted by Mr. Nasmyth, of Patrierift. The tool box slides on a top and bottom V, and is therefore less subject to any side deviation through wear. In front of the tool holder are two fixed bearings, carrying a cross shaft, through the centre of which is a socket holding a mandrel.

On the bottom end of this mandrel is fixed the wheel or pattern to be operated upon. On the top end is adjusted the dividing plate or apparatus. This mandrel has a motion in a vertical plane, and another motion horizontally; out of a composition of these two movements the varying depth and breadth of the bevel teeth are produced. The vertical motion is obtained by means of a worm working in a toothed segment. The feed motion is communicated by a cam on the driving shaft, working into a ratchet wheel. This wheel in its turn works the worm and segment. The depth of tooth for the bevel gearing is thus obtained. The form of the teeth is produced by means of a lever attached to the mandrel on which the work is fixed. In the other end of the lever is fixed the shape of the tooth upon a somewhat increased scale. This templet acts against a steel straight edge on a line with the tool. The vertical motion acting upon this lever works the tooth down, and thus transmits the motion from the templet to the tooth of the wheel being produced. The templet is kept against the steel straight edge by means of a spring. There is an ingenious spring and detent motion, throwing the vertical movement out of gear when the tool reaches the bottom of the tooth. The dividing plate, to which we alluded before, is set by hand when each tooth is finished, and it is kept in position by a lever and point. This lever is adjustable, in order to regulate the thickness of the teeth. The pitch is given by the holes in the plate. After cutting one side of the teeth, round the whole circumference of the wheel, a left-handed cutter is substituted for the previous tool, which we will suppose to have been right-handed. The templet or shaper is also changed to the other side. The machine is then put in motion to complete the shape of the teeth.

"In our volume 52, for 1850, p. 97, will be found an account (extracted from the '*Franklin Journal*') of 'a machine for cutting teeth for bevelled gear' then patented in America by George H. Corliss. The machine is not illustrated, but, as far as can be gathered from the description, its principle is slightly similar to the machine of Messrs. Hunt and Co. 'A reciprocating cutter that moves in a slide is used, which cutter vibrates on an axis that coincides, or nearly so, with the apex of a cone representing the bevel of the wheel to be cut, and by which vibration the

depth of the cut is determined.' It is thus seen that the *reciprocating cutter* is adjustable.

"The *work* is adjustable in Messrs. Hunt and Co.'s arrangement.—'Mechanics' Magazine.'

On the application of machinery to coal-cutting, a paper was read by Mr. Samuel Firth before the British Association, of which the following is an extract :—

"While excavating machinery is used with such success in the great Mount Ceniz Tunnel, it is not too much to expect its early introduction into our mines, under circumstances certainly not more difficult. Mr. Firth, in the course of his paper, said :—

"Numerous efforts have been made, during the last fifty years, to bring coal-cutting in mines under the influence of mechanical power; but in no case, I believe, except at the West Ardsley Colliery, has any continuous operation survived the experimental period.

"I do not expect that the introduction of machinery into coal mines for the purposes named would materially diminish the number of persons employed, but rather that the effect would be to meet the increasing consumption. That increase may safely be taken at two millions of tons per annum, and to supply this increase would require an annual increase of labourers amounting to about 3,500. Thus there will not be any displacement of labour.

"The steam-engine has a 20-inch cylinder, and the air-pump 18 in. The air is worked at a pressure of about 50 lb. to the square inch. The air is conducted down the shaft in iron pipes of 4 in. diameter, and thence to the workings (about 800 yds.) in gas piping, and down the face by india-rubber piping of 1 in. diameter, which is connected to the machine. The machine is moved on iron rails laid on cross iron sleepers, and is propelled a little, after each blow of the pick, by the hand-wheel. Generally, the machine is passed three times over the face of the coal, each time with a longer pick, to gain the requisite depth for taking down. The first cut being 18 to 20 in., the second 9 to 11 in., and the third from 6 to 8 in.; 36 in. being the depth aimed at and accomplished. The actual quantity of work done in six consecutive days of eight hours each, by one man with one machine, was 618½ yds., or about 800 tons of coal. The man is

attended by two boys, who clean out the groove, and remove the coal thrown out by the machine. In the West Ardsley seam a man will average $7\frac{1}{2}$ yds. of coal a-day, so that if the machine were worked by shifts of eight hours, three men and six boys would do the work of forty men, and that, too, the most severe and trying work in the pit.

"It must be understood that at West Ardsley the seam is somewhat favourable for the purpose. It is 4 ft. thick, having a good roof and floor, and is worked on the long-wall system, with a somewhat soft bareing part, about 12 in. above the floor, and in this the pick works. The comparison, however, with handwork is fairly made, because both work in the same part of the seam. The machine thus far has only been put to 'bareing,' or 'kirving,' but the proprietors expect to effect 'straight-work' by a different arrangement of the picks. The filling, and all other work of the pit, is untouched by this machinery. The air-power works admirably; and its use gives a cool and refreshing stream of pure air to the far-distant works, which issues from the cylinder at a temperature very little above freezing-point. It will not be necessary to say here that the air-power is acquired by a much larger measure of steam power; but this is not a material item at a colliery, where so much engine coal is almost worthless. I am not prepared with the exact commercial results or saving in cost, but at West Ardsley this part of the question is, I believe, eminently satisfactory. I have been informed that some experiments have been made, within the last few days, at the Hetton colliery, by the West Ardsley machine; and although the seam is of a hard nature, the kirving was done 3 ft. deep with a groove of 3 in. at the face and 2 in. at the back, giving an average cut of $2\frac{1}{2}$ in. high; whereas the average height of hand-kirving in the same seam is about 11 in.

"This saving of good coal from destruction is equal to an average of 9d. per ton upon the whole yield of the seam.

"Another machine of a different principle has been invented at West Ardsley, and promises to be a most useful one. It is on the direct-action principle, with a to-and-fro motion, from a cylinder mounted transversely upon the carriage, and regulated in a similar manner to the pick machine.

"This invention has not advanced so far as the 'pick,' but

some recent experiments have given most satisfactory results. The complete success of this machine will be of great importance, as it will be more effective in 'straight-work,' 'headings,' and 'drilling,' than the pick.

"In conclusion I may express the confident opinion that, at no distant period, every branch of mining will be accomplished by machinery; and if we look at those results from a humane point of view, the sooner they are realized the better it will be for all parties, and especially for the working collier."

We ourselves have repeatedly seen this machine in operation, and it is truly wonderful how simply and efficiently it does its work. The machine is so light and compact, that, if by any means the small wheels get off the rails, one man can with great ease lift the one end of the machine and replace it upon them. The machine we saw was one of the oldest and most used, and was literally covered with coal dust, and apparently had not seen a piece of cotton waste since its erection; withal this, however, its action was perfect, and the work was done apparently as well as if the machine had been made of the best workmanship possible. The admirable fitness of compressed air for working those machines is all the more marked when we consider that the exhaust serves to ventilate the seams. Other work is done in the West Ardsley Pit by means of this compressed air, instead of using horses, or in some cases boys and men, for propelling the trucks along the seams, a small winding engine is employed, worked by air, thus saving much labour and expense. The only defect in the use of compressed air to propel such machinery is the small percentage of power realized from it in comparison to the force required to compress such air. This is principally owing to the difficulty in utilizing the whole of the expansive property of the air in the coal machinery, while in compressing it all such expansive property offers the full resistance in compression. The loss also of latent heat is another source, as also friction, in compressing, &c. With all this there is not much more than 40 per cent. realized, and this under favourable circumstances only. A good air engine will materially reduce this loss, but when done, it is of little importance at the pit mouth where abundance of slack and other refuse capable of producing steam can be obtained.

So successful is the application of this machinery at the West

Ardley Pit that we do not consider ourselves too sanguine in cherishing the belief that in a few years the great bulk of the work in coal and other mines will be all accomplished by its aid, and this accompanied by a great saving of money, and what is of still vaster importance, a saving of human life. Recently, owing to the scarcity of labourers in America, machines have been sent out there, and there is every reason to believe that they will be generally adopted wherever they are at all applicable.

Boot and shoe making has within the last few years been greatly accomplished by machinery,—such machinery completing the work and leaving almost nothing to be done by hand. In America this machinery has been carried to the greatest state of perfection, owing to the demands of the war and the scarcity of labour. The '*Scientific American*' thus describes an establishment fitted up with such machines:—

“Three large apartments are occupied by the operatives, mechanism, and goods. The skins for the uppers are first spread out, examined, and selected according to the purposes for which they are required. Different cutters then cut out the respective parts according to the size and form required, and these are all arranged and classified. After this, these separate parts are given out in lots to be sewed by machines, and those uppers which are intended for boots are crimped, and the whole made ready for receiving the soles. The more heavy operations of punching, sewing, pegging the soles, and finishing the articles are next executed. The sole leather, in hides, is first steeped in a tank of water to soften it; then it is thoroughly dripped, and afterwards cut by a machine into measured lengths of a certain breadth, according to the size of the sole wanted. After having become sufficiently dry, these cut strips of leather are run between rollers, and also submitted to severe pressure under plates in a press, so as to effect as complete a compression of the fibres as is attained according to the old mode by beating with a hammer upon a lap-stone. From these compressed strips, soles of the different sizes are punched out at a single blow by a machine, the cutter of which is of the size and form required, and it turns round so as to cut a right and left sole alternately. Heel-pieces are also cut out by hollow punches at a single blow. The edges of the soles

and heels are next smoothed and polished in a small rotating machine; and another machine then makes the channels in the soles for the rows of stitching. After this, the under soles and uppers are fitted upon lasts and made ready for sewing. This operation is executed by Mackay's peculiar machine, adapted for this specific purpose. The waxed thread is wound upon a vertical spool, and is conducted through a guide situated on the top of an elbow secured on a swivel joint capable of turning under the needle, and conducting the thread into the crease around the sole. The needle operates vertically above the sole, and the waxed thread is fed into the interior of the boot or shoe by the guide, the needle descending through the sole, drawing through the thread and forming the stitches, which are pressed down close into the crease by a tracer-foot, upon which great pressure is exerted. In this manner the sole and upper are united firmly and neatly together in a few seconds, without employing a welt. Hand-sewing cannot be compared with such machine-work for accuracy and rapidity. Another machine is employed for putting on double soles with copper pegs. A thin strip of copper is fed in at one side and the holes are punched in the sole, the pegs cut and put into the holes, and then driven down at one continuous operation, with a speed corresponding to that of sewing the soles. The crossing of the half sole at the instep is pegged, and also fastened with a screw at each side by hand; the heels are also pegged down. The edges of the heels are neatly trimmed by a small rotating machine, and the soles are also rubbed down by a machine; so that nearly all the operations connected with the manufacture of boots and shoes in this establishment are performed by machines designed especially for the purpose. The legs of the boots are stretched and the wrinkles removed by new boot-trees secured to benches, and are expanded in an instant from the interior by pressing on a treadle with the foot. These boot-trees are altogether superior to the clumsy old wedge kind. The materials used in the manufacture of these articles appear to be of a superior quality, the machines not being adapted for operating on inferior patch leather. Another novel feature connected with these machines is that they are driven by one of Roper's hot-air engines, illustrated on page 97, Vol. VIII. (new series) of the '*Scientific American*.' It has been running for several

months, requiring but little attention and consuming a very small quantity of fuel. The accurate operations of these machines and the rapidity of their action place them in a highly advantageous position for manufacturing boots and shoes. The price of hand labour had become so high, and workmen so scarce, that such machines became a necessity, and the change effected by their use is equal to four times the quantity of work executed by hand labour—that is, one hundred men will turn out with these machines as much work as four hundred men without them. The saving of labour to the country is therefore immense. About 500 pairs can be turned out daily in this establishment. Perhaps no labour connected with boot-making is so severe as that bestowed upon burnishing the heel with a warm iron. This work is still executed by hand, but a machine is now being set up to accomplish this finishing operation, and it will soon be at work."

Type-setting machines.—"A lecture was delivered on this subject, on the evening of the 10th inst., at Stacy Hall, Boston, by Charles W. Felt, the inventor of a type-setting machine. It was given before the Boston Printers' Union, by invitation. Alluding to the efforts made by others recently to facilitate the composition of type, he said:—"Thomas N. Rooker, and John H. Tobitt, of New York, and Mr. A. H. Bailey, of the Boston '*Transcript*,' were mentioned as having devoted more or less time to improving the prevailing methods. Mr. Rooker has introduced into the '*Tribune*' office forty cases with moveable bottoms. In these cases the bottoms may always be kept conveniently full in composition, and in distribution the bottoms may be lowered so as to receive a large quantity of type. Mr. Tobitt's plan, and also that of Mr. Bailey, is that of uniting two or more letters upon one body, so that by one lift two or three letters are set up instead of one. Mr. Bailey's system of combinations is calculated to save from 20 to 40 per cent. in composition. When it is considered that the word *the* forms six per cent. of the language, and *and* about four, while many others exceed about two per cent., the advantage of a combination system is evident. The difficulty in the matter, as Mr. Felt alleges, is as to how many and what combinations *may be used with profit*. The use of type-setting machines, it

was claimed, would add 25 per cent. to the earnings of the printer; but the stronger argument in its favour is that it will add 25 per cent. to his life. Though the subject of combination type is one of primary importance, because so simple, and because yielding a gain which is a profit of itself, yet the great reform in printing is to be made by introducing machinery. In all machines hitherto invented no attempt has been made to justify. The possibility of justifying by machinery has long been doubted, but Mr. Felt contends confidently that there is no impossibility in the case. The types are set up in his machine in the usual order as the keys are touched, and the words are separated, not by the usual spaces, but by pieces of steel with beads by which they may be drawn out."—*'Scientific American.'*

Coming now to *agricultural implements and machines* we propose treating first of steam ploughs, an invention of comparatively recent date, but one of considerable importance and interest to the agricultural engineer and the public.

To do this most effectually we shall simply confine ourselves to the consideration of such facts as have elicited themselves at trials, &c. That the history and nature of steam ploughing may be better understood, we quote the following article from the *'Mark Lane Express':*—

"Steam ploughs may be divided into two classes—(1) those only adapted for ridge ploughing, and (2) those constructed for one-way ploughing, *i. e.*, for laying the furrow slices all in one direction, thus leaving the ploughed land without open furrows or ridges.

"Of the former of these two classes little now requires to be said, as the thorough drainage of land has rendered the latter preferable. But when steam ploughing was first proposed, and indeed up to a very recent period, ridge ploughing was essentially necessary to effect the surface drainage of a large area of land; so that steam ploughs had to be constructed for this kind of work. To overlook this fact in our notice would be doing an act of injustice to several of our most talented pioneers who merit the contrary at our hands.

"Of ridge steam ploughs, for ploughing land lying in ridges, and for drilling for turnips, we may mention those of Major Pratt, patented in 1810 (No. 3,309); Campbell and White,

patented in 1839 and 1840 (the former No. 8,108 and the latter No. 8,517); Clarke, Freeman, and Varley, 1846 (No. 11,077); and Osborn, 1846 (No. 11,304). Into their mechanical details it would be a waste of time and space to go. As old patents, those of Campbell and White possess the most merit and attention of inventors.

"One-way steam ploughs have been constructed on two plans—(1) the two sets of ploughs being placed heel to heel, and (2) the two sets placed share to share. The latter only merit a detailed notice. To the former we shall merely refer, as in the case of ridge ploughs.

"Of patented steam ploughs, the two sets placed heel to heel, those of Major Pratt and Osborn above, may be mentioned, and more recently Lacy in 1855. Of those reduced to practice not under patent, the example of Lord Willoughby de Eresby merits the most favourable notice. The chief difficulty experienced is the position of the furrow wheel of the carriage; but into details of this kind we shall not enter, as the system has been superseded, at least for the present.

"One-way steam ploughing, as now practised by those using Fowler's steam plough, has many things to recommend it; and the first implement of this kind on our list of patents is M'Rae's. It was successfully reduced to practice in Scotland, being constructed on a plan differing in several parts from what is represented in the drawing accompanying his specification (No. 8,329, A.D. 1839), and was shipped to Demerara. But, previous to this, various propositions were enunciated for ploughing land on this plan by agriculturists, engineers, and others; and of these one was patented by a Mr. Pinkus (A.D. 1839, No. 8,207) resembling in some points that of M'Rae's. The latter, consequently, in the reduction of his proposition to practice, had to avoid the infringement of the former's patent, and it will therefore be necessary to notice the peculiar claims of Pinkus' implement, so as to be able to solve the interesting problem as to who is really 'the father of the steam plough,' and also to establish a no less important question as to what is public property in the steam ploughs now at work in our fields, and for which farmers are called upon to pay long prices.

"Mr. Pinkus had two patents—the above that preceded

M'Rae's, and another in 1840 (No. 8,644). In neither case does he lay any claim to novelty in the construction of his ploughs. Indeed, between 1831—when the committee of the House of Commons gave to the public its memorable report in favour of steam-locomotion on common roads—and 1840, steam ploughs actuated as proposed by Pinkus was the common conversation of hundreds of intelligent farmers, whenever they met. In the 'Quarterly Journal of Agriculture,' vols. v., vi., and vii., the subject will be found discussed in a series of able articles, including a full account of Heathcoat's experiments of steam ploughing at Red Moss, Burton-le-Moors (vol. vii., p. 227). In vol. v., p. 480, reference is made to a Mr. Thomas Gibbs, who had a model of a 'travelling steam plough,' and also a rope system of hauling, or, as it is there called, of 'towing' steam ploughs between two engines, one on each headland. But, however interesting a detailed account of such would be, our limits will not permit us to go farther into the history of the steam plough and the rights of the public.

"Pinkus, in his specifications and drawings of both his patents, merely gives a popular outline of what M'Rae or anybody else may do, without infringing existing patents. In other words, the mechanism of his ploughs and mode of yoking two sets below a carriage-frame borne on four wheels, one set for ploughing one way, and the other the opposite, were then public property, and, hence, cannot now be claimed by grasping and monopolising patentees, so as to prevent others improving such mechanism and modes of yoking, thereby going a-head and leaving them behind in the march of progress.

"In both drawings only a part of the implement is shown, while that portion is not drawn to a scale, so that they are not only mechanically defective, but wanting in detail; consequently, one requires to be acquainted with the progress of things at the period, to understand the drawings of either patent.

"The object of the patentee (Pinkus) evidently appears to be the illustration of variety, the two sets in the drawing of the first patent being mechanically unlike each other, while both differ widely in mechanical construction from the two sets of ploughs shown in his patent of 1840. In the former, from reference being made to the handles of plough No. 4, it is mani-

fest that each plough had an individual action, and was held by its own ploughman. On reaching the headland the copse of the plough is screwed up to the frame by the attendant on the carriage, so that the plough would heel out, as in the case of the common plough. The three ploughmen would then fix up their ploughs to the framing behind, as shown in the drawing; then go to the opposite end of the carriage, and let down each his respective plough for the reverse movement. Now, this, at the time, was a very common proposition. In the second patent, again, each set of ploughs is rigidly fixed to a diagonal bar, the four ploughs in each having a common beam. This is neither more nor less than a four-furrow 'Somerville plough,' as they were then called, with a common beam under the carriage so as to expedite the screwing-up of the copse, to take them out of the ground and let them into it with equal despatch. This was also a very general proposition between 1830 and 1840, but objected to as involving a sacrifice of mechanical principle, and what is worse, the subjecting the farmer to hard work at each headland.

"This highly objectionable feature of rigidly fixing the ploughs, either in a frame or on a diagonal beam, so as to enter together at the one headland, and to be taken out in a similar manner when they reach the opposite, on the Somerville plan, merits a special notice, as it is now being generally adopted. Practical agriculturists have, from the first experiment of the Somerville plough, condemned it without ceremony, owing to the bad work it makes at the headland—the loss being much greater than the saving of manual labour counterbalanced. In horse culture this objection to the Somerville plough is unanswerable, and under steam-culture a different conclusion cannot be arrived at either practically or scientifically. We are not insensible to the difficulty of entering and taking out sets of ploughs, three and four being in each set; but that does not justify the sacrifice of mechanical principle, much less the making of bad work at the headlands. With the latter—bad work—farmers are familiar. We never heard it estimated at less than double the ploughman's wages—*i. e.*, about 5s. per acre. It is one of those valid objections to steam ploughing, as now performed, that greatly increases the expense, and thus stands in the way of progress. As to the

former—the sacrifice of mechanical principle—this we shall examine under Fiske's implement, as our remarks will be better understood after noticing M'Rae's steam plough, which is free from this cardinal objection.

"As the writer has determined on having a steam plough made on M'Rae's plan, exactly similar to the one that was made by the Messrs. Thomas Edington and Sons, Phoenix Ironworks, for the patentee, and successfully tried on the lands of Possil, near Glasgow, and worked by him on his own plantation estate afterwards, in order to prove that he (Alexander M'Rae, Esq., of the county of Demerara, British Guiana, planter), is the legitimate father of the steam plough, a general description of the implement is all that will be necessary at present, a promise being given that a drawing of it, with the usual descriptive details of its mechanism, shall be forthcoming at no very distant date.

"Like too many similar projects, M'Rae's appears to have been patented before it was reduced to practice. This, generally speaking, is a prudent course to pursue, and perhaps upon the whole the freest from objection, were patents less expensive to obtain; for, in the carrying out of such projects, new discoveries are often made in the manufactory and field, which require a second patent to cover them. And this was the case with M'Rae's steam plough, for his specifications and drawings do not wholly cover it. In other words, the improvements made, when his project was placed into the hands of the above engineers to carry out, were such as to justify a second patent; but the exorbitant charges of the Patent Office at that time, we presume, prevented this, and also the general public, from getting the information which otherwise they would have derived from the specification and drawings of the improvements just mentioned. The loss thus sustained by the public may to some extent be yet counterbalanced by placing a model of M'Rae's steam plough in the Patent Museum at Kensington; and this national duty, we hope, her Majesty's Commissioners of Patents will not fail to perform, seeing that they have ample funds at their command legitimately available for this important purpose—one which could not fail to stimulate the progress of invention in steam culture.

"According to the drawing that accompanies M'Rae's speci-

fication, a carriage-frame suspended below the axles is borne on four wheels—two furrow wheels and two land wheels—and is furnished with two sets of ploughs, three in each set, placed share to share, as shown in the drawings of Pinkus' first patent, one set having right hand turnovers, similar to those of the common plough, for ploughing from the engine in the punt to the anchor in the other punt in the opposite canal, the other set having left hand turnovers for the return movement. In construction the ploughs and plough-beams differ considerably from common horse ploughs, or from those of Mr. Williams' (Baydon, Wilts), Halkett's, and subsequent examples of a similar kind; but in principle they may be said to be alike; and when in action they perhaps more resemble Fiskens's, owing to the beams in both terminating somewhat abruptly immediately before the coulter, than any of the other examples now in the field. The beams, together with the draught-bar and two suspension bars of M'Rae's ploughs, obviously involve the principle of a 'parallel motion,' as it was sometimes termed, to which the drawing does not do justice. Long prior to the date of his patent, the principle of a parallel movement was discussed amongst practical farmers who had received the necessary education to do so, such as was taught at Edinburgh, Aberdeen, &c., where hundreds of Scotch farmers were annually thus qualified; and looking at M'Rae's drawing, we are led to the conclusion that he contemplated the solution of this problem; but if so, he has evidently failed. Into the mechanical details of such a problem it would be foreign to the object of our present series of papers to enter, as its solution has not yet been reduced to practice. Coleman and Sons, it is true, showed something of the kind at Chelmsford, in 1856; but it was defective in several points.

"It is but justice to M'Rae and his patent agent to observe that, at the date of his patent, drawings were not made with the same accuracy as under the present statute, and his drawing appears rather to illustrate principle than the details of mechanism, so that it would be highly uncharitable, if we are right in this hypothesis, to examine it in any other light, more especially as the invention or principles thus illustrated were immediately reduced to practice, as already stated.

"According to the drawing, therefore, the draught-bar and

beams when in action would be rigid, thus forming a leverage of the second kind; the fulcrum, when the plough is lowered into action at the one headland, or taken out of the ground at the opposite end of the field, being the draft-pin of the copse by which it is hauled when ploughing. Six vertical bars are bolted to the carriage-frame, three towards each end, each bar being directly above the body or frame of its own plough. These vertical bars are for the lowering and elevating apparatus, which consists of six vertical suspension-bars, working each in two guides, the lower end being fixed to the frame of the plough, apparently a little behind the centre of gravity, and actuated at the upper end, which passes through a slot, by a lever. Near the one side, and towards the top of the upright bars, are seen the pins, upon which the levers work. Below the frame of the carriage are four small pulleys for guiding the draught-rope or chain, and keeping it from getting entangled with the ploughs; and upon the carriage above is shown a hand-rail, for the accommodation of the ploughman.

"The canals in Demerara, we may observe, 'run parallel to each other, and at a distance of from two hundred and forty to three hundred and sixty feet apart,' quoting from M'Rae's specification.

"The improvements made in M'Rae's steam plough, already referred to, are chiefly these. Instead of four carriage wheels, as previously adopted by Pratt and Pinkus, and subsequently by Fiskien, viz., two furrow-wheels and two land-wheels, two main central wheels are substituted, as subsequently adopted by Fowler and Grig, one on the furrow and the other on the land between the two sets of ploughs, while two smaller wheels are placed one at each end of the carriage-frame, now lengthened beyond the ploughs, so as to enable the implement to cross the open ditches between the canals, used for bottom irrigation in dry weather and surface drainage in the rainy season. These alterations were essentially necessary to the successful working of the implement in the low-lying plantations of British Guiana. The other improvements have reference chiefly to alterations in the plough-beams and apparatus for lowering and raising the ploughs.

"We have already expressed a high opinion of the principles

upon which M'Rae's steam plough is constructed; and it is but just that we should here observe that the opinions thus entertained are not based merely upon a knowledge of mechanics, but also upon its successful working near Glasgow, and also of the equally successful working of Halkett's ploughs, made on exactly similar principles, the one experiment corroborating the other, thereby proving the soundness of the conclusion. Leonard Wray, Esq., in his valuable work, 'The Practical Sugar Planter,' published so far back as 1848, by Smith, Elder and Co., 65 Cornhill, London, speaks in the highest terms of the triumphs of steam ploughing in British Guiana, as the following quotation will show:—

"'As the plough arrives at the extremity of the field the two boats move on the required distance; then the motion of the engine is reversed, and the plough returns, so that by this simple arrangement the ploughing of an estate is accomplished most expeditiously. The Demerara planters deserve a very great deal of commendation.'

"We might quote other authorities from our West India colonies, but the above is sufficient. That M'Rae's steam plough is capable of improvement will readily be granted. Indeed, this is the reason why we are determined to have it constructed anew, and hauled by wire ropes.

"An account of the experiments with M'Rae's steam plough 'on the lands of Possil, near Glasgow,' as referred to above, will be found in the '*Mark Lane Express*,' April 27, and November 16, 1840, and '*Farmer's Magazine*,' for June, 1840, and also in the number for December of the same year, the former quoted from the *Glasgow Herald* and the latter from the *Glasgow Courier*. Both reports pronounce the experiments 'eminently successful,' the expression of approbation just quoted being from the former paper (the *Herald*). Temporary canals were formed to test the working of the two punts, the one carrying the engine and hauling-drum, and the other the anchor-pulley as well as that of the implement. As might be expected near the enterprising city of Glasgow, a large concourse of the landowners and farmers of the neighbourhood were present at the trial, as also engineers, including the writer, who was in Glasgow at the time. The highest praise was justly bestowed upon Mr. M'Rae and the

Messrs. F. Edington and Sons by all who were qualified to pronounce an unbiassed opinion on the subject."

The meeting of the Royal Agricultural Society for 1863 was held at Worcester. The trials of most of the implements and steam engines were competitive prizes being awarded to many successful makers. Of the agricultural or portable engines we have already treated under the section devoted to locomotives. In the course of a somewhat cursory and hasty examination we did not see any decidedly new or novel implements. Perhaps the most original implement was that of a chaff cutter, exhibited by A. B. Childs, the invention of Messrs. Gittus and Leggett of Mildenhall, Suffolk. The blades were straight and moveable on the wheel, in place of being fixed and curved, and had the proper angle so as to obtain a drawing cut given them by means of a fixed eccentric, the inner extremities of the knives being conducted to a strap, which, much on the principle of feathering paddle wheels, gave the necessary and constant angle of cut. This machine was of necessity complicated and expensive, and we can only regard it as an ingenious and novel substitute for the curved knives; but we are strongly disposed to think that for simplicity, and cheapness, and perfection of cut, nothing can ever supersede the knife of a proper curve.

Another new thing—if we may so term it, for it is rather the application of a novelty than a novelty itself—is the greatly-spread adaptation of Bruckshaw and Underhill's elevator to thrashers; an improvement effecting a great simplification of these still much-to-be-simplified machines. Its general principle may be said to simply consist in the grain being brought into immediate contact with the blades of a common fan; the grain is thus cleaned and elevated by the conjoint action of the percussion, centrifugal force, and the blast, generated by the revolution of the blades. The bringing forward of this valuable arrangement has directly and indirectly effected quite a revolution in thrashing machines; and we have probably not yet seen the last and most forward shape in which this improvement may be carried out. It is, perhaps, not generally known that this adaptation of the common fan has been proposed nearly a century and a half ago, and has been in extensive use for many years by our ingenious neighbours across the channel.

Coming now to the trial of steam ploughs, the report of which we extract from the *Practical Mechanics' Journal*:—

"The stewards of this department were Sir Archibald M. Macdonald, Sir Edward Kerrison, and Mr. Torr, who were assisted, during the trial of steam ploughs, by Mr. Amos, the society's consulting engineer, and by four engineering and practical judges.

"Mr. Hayes, of Stony Stratford, sent a stationary engine and windlass. The peculiarity of his system was that no signalling is required, the anchormen at the ends of the work stopping the action of the windlass at pleasure by means of cords laid along the field for the purpose. This is an advantage in foggy weather, or when working by moonlight, and lessens the chance of a breakage from inattention of the engine-driver. The winding drums are driven by band-wheels; the engine strap being shifted from one to the other as required, and thus no wheelwork has to be put in or out of gear, and by the simple movement of a handle the pulling drum is instantly stopped, the rotation of the paying-out drum arrested by a steam-pressure break, and the motion of both drums reversed. The implement worked was one of Mr. Fowler's cultivators; but unfortunately an accident occurred which prevented the prosecution of the experiment.

"Mr. Smith, of Woolston, sent a three-tined cultivator, driven by a double-cylinder 10 horse stationary engine. Mr. Smith has much improved his combined cultivator and corn drill. The framing is now light, but very strong, balanced upon a pair of wheels, so as to be turned round with the utmost ease, and guided with accurate precision in a straight line. With this implement nine rows are sown at once in a beautiful seed-bed, crumbled by the tines out of moist ground previously untouched by any tool whatever. The saving of labour in ploughing and repeated harrowings, and of time in seeding wheat or barley, has proved of vast advantage on clay lands.

"Mr. Steevens, of Hammersmith, was one of the competitors, but the machinery was disabled by an accident at the commencement.

"Messrs. Savory and Son, of Gloucester, hang a 6 ft. drum upon friction rollers around the boiler of a double cylinder 10-horse engine. The cylinders are placed transversely in front of

the smoke-box, and the crank-shaft, passing alongside the boiler and within the drum (which is a cylindrical shell without arms or spokes), carries pinions which gear with internal teeth on the drum, and also a screw or worm, which actuates one of the travelling wheels when the engine is required to advance. The drum, being large enough to carry 500 ft. length of rope in a single layer of coils, hauls the implement by winding up the rope that runs singly across the field, and a similar engine on the opposite headland pulls the plough again to that end of the furrow. A couple of guide rollers traversing in front of the drum upon a revolving screw shaft, feed the rope on to the drum so regularly that no coil grinds against or overlaps another. While one engine is hauling the other is simply allowing its drum to run free, besides advancing a few feet along the headland into position for the next furrow. The implement worked was a Fowler's plough.

"Messrs. J. and F. Howard, of Bedford, with a double-cylinder 10-horse portable engine, a stationary windlass with coiling drums, the rope laid out around the plot, and the slack rope held up off the ground by a 'compensating pulley' (which accomplishes this with a much less waste of power than is occasioned by applying a break to the paying-out drum), worked their three-tined cultivator, making capital work, full 7 inches deep at the rate of about 11 acres in 10 hours. This firm has brought out a steam plough of very novel construction. The balance principle is altogether dispensed with, excepting so far as the general equilibrium of the machine is concerned, so that the tendency of the set of ploughs in the air to lift the other set out of work is now avoided. Two sets of plough bodies upon two beam frames are hinged to opposite ends of a three-wheeled carriage frame, and the weight of each set of ploughs is sustained by a coiled spring in a box. But the action of the parts is so adjusted that when a set of ploughs is at work, the spring exerts but a slight upward pressure; when the ploughs are raised the spring gains greater power, and, when they reach the highest point, bears up the whole weight.

"Mr. Fowler, of Cornhill and Leeds, has improved upon his apparatus for employing the common portable engine. The rope passes across the field and back again, distended between the

pulley on the self-travelling anchorage and the 'clip-drum,' which hauls the rope, not by coiling, but by gripping it tightly in a groove formed of moveable and self-acting pinching pieces. The drum is hung beneath a carriage, which has sharp blade-flanges upon its wheels (removed for travelling upon hard roads), cutting into the ground and withstanding the side pull of the rope, and the carriage advances at intervals along the headland, taking the engine with it. Of course, a driving belt could not be employed to transmit the motion of the engine fly-wheel to a band-wheel upon the carriage, which alters its distance and posture at every advance. A chain of hard-wood blocks, in V-shaped grooves, answers admirably, and will probably wear extremely well. Owing to the loss of a plug, and a disarrangement of the pump, the engine made too many stoppages for time to be taken into account in its working of the balance plough with 'digger' breasts at about 9 in. depth. Besides this form of apparatus, Mr. Fowler has also his clip-drum hung underneath the boiler of a self-propelling engine; and, again, an arrangement for two engines, one at each end of the furrow, but each with a coiling drum underneath its boiler, instead of a drum engirdling it, as in Messrs. Savory's invention.

"The system of Messrs. Coleman is different from any other, in having two implements alternately hauled in work toward the engine on one headland, and then back again out of work toward an anchored pulley on the opposite headland, the ropes being coiled upon two drums hung at one side of the engine. The double-cylinder 10-horse engine worked two 5 tined cultivators at a depth of 8 in.

"Mr. Collinson Hall, of Navestock, has superseded the use of wire-rope in his apparatus by a chain of round steel bars and short flat plates and rivets at the joints, the drum and the anchorage pulley being seven or nine sided, instead of circular. Very little wear appears upon the present chain, which has worked over 400 acres, and the rivets can be replaced at a trifling cost; but time will soon decide whether a chain that cannot be carried with advantage over friction rollers may compete with wire-rope that both Messrs. Fowler and Messrs. Howard hold clear off the ground in order to effect a great economy of motive power and of costly wear by friction on clods and stones.

"The competitors who had not been disabled by accident were set to work in a field of hard old lea, when the time of moving out of one field with the apparatus packed up for travelling, and setting down in another field half a mile away was noted with the following results:—

"Mr. Fowler was 55 minutes moving with eight horses, and finished his two acres in 1 hour 51 minutes; Messrs. Howard moved in $1\frac{1}{2}$ hour with eight horses, and completed their two acres in 1 hour 57 $\frac{1}{2}$ minutes; Messrs. Savory moved in 25 minutes without any horses at all, and finished their two acres in 1 hour 40 minutes; Mr. Smith moved in one hour with eight horses, and finished his two acres in three hours and one minute. The depth was about seven inches in all these cases; the fuel consumed differed considerably—Fowler's was 3 cwt. 1 qr. 2 lb., Howard's 3 cwt. 1 qr. 19 lb., Savory's 5 cwt. 1 qr. 10 lb., and Smith's 3 cwt. 3 qr. 21 lb.

"On a subsequent day the cultivators were tested on some heavy, hardened land, and the result was in favour of Mr. Fowler's machinery. If in common turn-over ploughing on the light land Messrs. Howard and Mr. Fowler made equally beautiful work,—the perfection of the Bedford mouldboards accomplishing the most neat and efficient turning of the slice,—on the heavy ground Mr. Fowler's 'digging' shares have far surpassed the cultivators of Messrs. Howard and Mr. Smith. In fact, no such wonderful work has ever been shown before; the immense slabs of indurated clay being riven up and thrown, not for several inches, but for several feet. It appears to be established that the stationary engine and windlass do not fall much behind the moveable engine and anchorage in amount of performance, provided the rope be well carried clear off the ground; and that the employment of one engine is most economical and best adapted for single farms, though (as proved by Messrs. Fowler and Savory) two engines may be most advantageous for working by contract, when frequent removals and much travelling from field to field are necessarily encountered.

"Mr. Seaman's patented improvements in agricultural implements, to be used in the cultivation of the soil, deserved notice. *These improvements are partly applicable to ploughs, cultivators, and harrows, and consist firstly of a peculiar arrangement and*

mode of applying leverage to the frame of a cultivator, so that by pressing down a lever it causes all the tines and shares to rise equally from the ground; and secondly, to the mode of forming that part of a cultivator, known as the share legs, with the view of obtaining lightness with great strength. Instead of making them of solid bars the inventor uses two light bars put together, with small struts and rivets, so that when looking at the front of the stalk or line there is a space between the two bars, and on taking a side view of the same stalk the upper part is in two parts, one lying behind the other, but meeting towards the front when they are welded together. Various other improvements in details have also been invented. Mr. Seaman has also invented a peculiar method of constructing wheels for ploughs, cultivators, or other wheeled implements; and he has improved the construction of whipple trees for the purpose of applying power to the draught of agricultural implements and machinery.

"The prizes for the best application of steam power for the cultivation of the soil have been thus awarded:—The gold medal to Mr. John Fowler; and the sum of £50 has been divided, £30 to Mr. Fowler, and £20 to Messrs Savory. The prizes for the best application of steam power which may be effectively and safely adapted for small occupations have been thus distributed: £25 to Mr. Fowler, £15 to Mr. Smith, and £10 to Messrs. Howard. To Mr. Steevens a silver medal has been awarded, whilst Messrs. Coleman have received a commendation."

At the Smithfield Club meeting held at the New Agricultural Hall, Islington, a very rich display of implements and engines took place. The following is an extract from a report by the '*Mechanics' Magazine*.'

"Anything like a detailed description of the implements exhibited would at once exceed our space, and prove uninteresting. Literally speaking, the visitor might walk through the building east and west, north and south, without discovering anything very new. Perhaps the most remarkable feature of the Exhibition lies in the self-propelling engines. In the International Exhibition of 1851 there was not one traction engine; and it is not perhaps saying too much, to state that a general belief existed that none could be contrived to answer any commercial

purpose. All that is changed now ; and, both in England and in the colonies, road locomotives, day by day, act a more prominent part. Our readers will doubtless recollect what an important class they formed at Kensington last year, and some progress has been made since. Makers of this description of steam machinery daily become more enterprising, and the dimensions of three or four of those shown at Islington, would have put the railway locomotives of twenty years ago to the blush. Messrs. Aveling and Porter, Garrett, Clayton and Shuttleworth, Fowler, and Howard are exhibitors in this class. The workmanship of their engines is generally speaking good, although individual arrangements are not yet all that they should be. In the first rank we must place an 8-horse engine, by Messrs. Aveling and Porter, which appears to us to meet almost every possible requirement in the most efficient manner. Perhaps there is not at present a firm in existence which has had so much practical experience in the road locomotive. Although their engines are, comparatively speaking, a thing of yesterday, Messrs. Aveling and Porter have completed altogether ninety-seven engines of the kind, ninety-six of which are in use. The engine exhibited is of 8-horse power, according to the method of calculation adopted by the Royal Agricultural Society, having a 9 in. cylinder by 12 in. stroke. The gross weight full, is about 9.5 tons. The general arrangements are too well understood to need description ; and the only novelties embraced in the present engine are a simple modification for obtaining two speeds, and an improved method of taking up the slack of the chain. Close behind the fly-wheel shaft a second is placed, carrying two spur wheels of different diameters, which are put in motion by pinions on the fly-wheel shaft. Either of these wheels can be placed in gear by simple means, according as the fast or slow speed is required ; the other, of course, being thrown out for the time being. This spur-wheel shaft is supported in brasses, which can be moved up and down as occasion requires in curved brackets bolted to the boiler. These brasses rest on iron packing pieces of various thicknesses. When the chain becomes too slack by wear, it is only necessary to raise the shaft and brasses in the curved *plummer blocks*, and replace a thin packing piece by one a little *thicker*, to take up the slack of the chain. The whole arrange-

ment is kept tight by suitable set screws, and answers its purpose in the most efficient manner: it being impossible, with the most moderate amount of care, to put the second shaft out of parallelism with the first. The chain is made with solid block links 2 in. wide, each finished in the shaping machine. Thus, a large bearing surface is provided, and wear is reduced to a minimum. It may not be out of place to state that one of these engines, of a somewhat larger size, has travelled over 5,000 miles of country roads, and is still a very efficient machine, having on one occasion drawn 26·5 tons, in addition to its own weight, up an incline of 1 in 12, 502 yards long, a performance almost unique.

“Messrs. Garrett and Son show a very neat single cylinder 8-horse self-propeller, embodying Mr. Aveling's patents. The cylinder is placed in the smoke-box just beneath the chimney. This engine is without the double speed gearing. The driving wheels are 3 ft. 6 in. high, and very wide on the face. It is the only road locomotive in the Exhibition provided with springs, if india-rubber blocks, fitted in a very simple and ingenious axle-box, deserve the name. It is strange that engineers should wilfully shut their eyes to the advantages to be derived from the interposition of a flexible medium between the dead weight and the carrying wheels. It is in vain to urge that, at slow speeds, expedients of the kind are unnecessary. We never could understand why speed should be kept down to the same rate with an unloaded as with a loaded engine. One of the best traction engines we ever met with, could draw 30 tons comfortably on a good road at $2\frac{1}{2}$ miles per hour, and run light, at from 7 to 8 miles with the greatest ease, thanks to the long easy springs so universally eschewed. That they form an item of expense at first, we admit; but the saving which they effect in the subsequent outlay for repairs far exceeds their first cost. Messrs. Garrett also show a well arranged double cylinder portable 12-horse engine; a 13-row corn drill; a very good finishing thrashing machine, with a single fan on the drum shaft; and several other articles, the workmanship of which is quite good enough to maintain the well-earned reputation of the firm.

“Clayton and Shuttleworth exhibit a traction engine, intended for Egypt; the cylinders, 8·5 in. diameter, by 14 in. stroke, are placed in the smoke-box just beneath the chimney; the driving

wheels, nearly 7 ft. high, have cast-iron cellular rims and wrought-iron spokes. The general arrangements of the machine are very good, and the workmanship excellent. The driving gear is so very peculiar, that, without drawings, it would be impossible to give an accurate idea of it. Suffice it to say, that the driving wheels each revolve loose on the main axle, which is immoveable. Just in the rear of the boiler, and at a convenient height above the fire-door, runs a transverse shaft, carrying a differential system of gearing at the ends. This shaft is driven by a pitch chain from the crank axle. Inside each driving wheel is bolted a large spur wheel, put in motion by the transverse shaft and differential wheels. The whole affair looks complicated, but is really very simple. The effect produced is, that so long as the resistance is the same to both drivers, they will both be propelled with equal velocity. If, however, the engine is in the act of turning a corner, the inside wheel will simply remain at rest, or nearly so, because the action of the steering gear places an obstacle in the way of its progress; the outside wheel will then advance at a speed as much greater than its normal velocity, as that of the inside wheel is less. Thus, if one wheel were blocked, the other wheel would proceed at a double velocity, the engine shaft still making only the same number of revolutions; and this action is so perfect, that the steering is effected with the greatest possible ease. The whole arrangement is extremely ingenious, and being well carried out with cast-steel pinions, &c., should prove very durable. The steering is effected by an endless screw and pitch chain; the principle involved being none of the best, inasmuch as the screw offers a nearly rigid *point d'appui* to any force impressed on either fore wheel by obstructions on the road, and the chances of stripping the teeth of the worm wheel are materially increased in consequence. While speaking of the fore carriage and its connections, we may remark that no universal joint arrangement is provided to permit either end of the axle to rise or fall independently of the engine. This may seem trifling; but it is on such trifles that the success of the road locomotive depends. It is folly to attempt to compel an engine to proceed over irregular ground on four rigid points of support. A swivel joint in front obviates the difficulty by reducing their number to three; the entire machine is spared many a strain thereby, and

the operation of steering is greatly facilitated. Messrs. Clayton and Shuttleworth also exhibit a double cylinder stationary engine, fitted with expansion gear; a thrashing machine; portable engines, &c., of excellent workmanship and good design.

"Messrs. John Fowler and Co.'s stand presents little with which the public are not perfectly familiar, save a rather coarsely got-up traction engine, intended to carry an underneath clip drum. The driving gear is completely boxed up within a heavy plate-iron inclined trunk, carrying the outside bearings of the shafts, so that it is not very easy to determine what it is like. The steering gear is in one sense extremely neat and compact, yet as unmechanical and defective in principle as it well can be. A large hand wheel on the foot plate, far removed from any bearing, puts an endless screw in motion, through the medium of some gearing and an inclined shaft about 18 ft. long. The endless screw takes into a very small, quadrantal, toothed arc on the fore carriage. This certainly does not look like good engineering. The foot plate of a traction engine is generally far too small to render it advisable that the steersman should discharge his duties there. So long as a locomotive is intended merely for ploughing, the arrangement may be tolerated, because the engine-driver can guide the engine forward for the few yards required at a time. The machine in question, is, however, set forth as a traction engine to which the winding drum *may* be attached, if deemed desirable; and such being the case, the steering wheel has no business on the foot plate. An engine and windlass, similar to that shown last year at Kensington; a set of ploughs, cultivators, &c., are highly creditable to the makers, and appeared to meet with thorough appreciation from the public.

"Messrs. Howard exhibit a set of their patent steam-cultivating apparatus, including, of course, the inevitable 10-horse self-propeller, by Clayton and Shuttleworth, and very similar in every respect, save the absence of differential gear, to the one shown by that firm and already described. The workmanship of all these articles is above the average. The merits of the system are too well known to require comment.

"Messrs. Hornsby and Son exhibit a very highly finished double cylinder portable 10-horse engine, suitable for ploughing or other purposes. The cylinders are placed in a steam chest over the

fire-box. The propriety of using longitudinal wrought-iron stay rods from the cylinder covers to the crank-shaft brackets, is more than doubtful. The boiler must expand far more than they can, removed as they are from any direct source of heat; hence, a tremendous strain must be exerted on the cast-iron brackets, which appear to be quite strong enough in themselves to support any legitimate strain to which they may be exposed, without the aid of such questionable expedients. We noticed a very ingenious and carefully got up reaping machine, in the same stand, which delivers the corn from an inclined table, by means of a patented arrangement of endless chains, provided with fingers, which sweep off the cut corn and place it by the side of the machine. Messrs. Hornsby also exhibit an excellent thrashing machine, ploughs, and many other articles.

"Messrs. Tuxford and Son show a 10-horse power patent 'housed' engine, got up as usual with great care, an Appold centrifugal pump, saw-bench, &c., which call for no particular remark.

"Messrs. Barrowes and Carmichael exhibit an 8-horse portable engine, one of the best of its kind, as far as neatness, simplicity, and good workmanship are concerned, that we have ever seen. The cylinder can be removed from the boiler with the greatest ease; all the bolts being accessible without removing the lagging. The crank is slotted out from the slab. The cross-head is peculiarly elegant in its construction. The position of the cylinder on the centre of the fire-box shell is objectionable, however, as it entails a very high crank-shaft. The engine is provided with steel volute carrying-springs—an arrangement which we trust will soon become more general.

"Mr. F. H. Wenham exhibits the most remarkable engine within the walls of the Agricultural Hall. This little machine, weighing barely $2\frac{1}{2}$ tons, and scarcely larger than an ordinary $2\frac{1}{2}$ -horse portable, has indicated full 16-horse power. It is provided with a high and low pressure cylinder, placed one at each side of the chimney, on the haunches of the smoke-box. The smaller of the two is 5 in. in diameter, the larger $8\frac{1}{2}$ in.; the stroke of both being the same, 12 in. The cranks are placed at an angle of 90 deg.; steam is led direct from the boiler to the small cylinder, the exhaust steam from which is conveyed to a superheater in

the smoke-box, the tubes of which are coincident with the boiler flues, so that both may be swept out at one operation. The steam dried and increased in volume, by a temporary sojourn here, is then led into the large cylinder, from which it finally escapes into the chimney. All the arrangements are simple and scientific, and we can very well credit the statement of the patentee, that he has obtained 16-horse power with about 32 lbs. of coal per hour. Indeed, indicator diagrams, with which we have been favoured, leave no room for doubt as to the actual powers of a machine, which well deserves the favour of all employing portable engines. The small weight for a given power is in itself no slight advantage in a hilly or difficult country.

"Mr. Collinson Hall exhibits a model of his ploughing apparatus; some illustrative drawings; and a steel link rope, constructed on his principle, which has ploughed over 600 acres of stiff land and looks none the worse. Mr. Hall eschews the wire rope, preferring one made of steel rods each about 18 in. long and half an inch in diameter, jointed to the next by two small, flat, steel links. The windlass employed is polygonal, and thus slipping is altogether avoided without any peculiar mechanical expedients. Mr. Hall's drawings illustrate a system of working by which the engine (or engines) rests stationary outside the field to be ploughed, two anchors being employed, between which the implement travels. The anchors are supported on small iron wheels, which proceed along the headland automatically, on rails, consisting simply of $2\frac{1}{2}$ -in. angle-iron bars of such a length that they can be conveniently moved by one man. The flanges support the anchor wheels, and prevent that important member of the system from yielding to the strain of the rope. The angle irons are retained in position by broad stakes driven into the soil, against which they bear. The anchor man takes up the bars as they are left behind, and, having previously driven the stakes, puts them down in position to receive the wheels as the anchor advances. We have, before now, spoken in terms of praise of Mr. Hall's system, which is, we believe, really one of the best yet developed. Its economy is not its least recommendation; while its simplicity, and the ease with which the mechanism necessary can be managed, and repairs effected, render it eminently suitable for situations where the aid of skilled

labour is obtained with difficulty. Mr. Hall's apparatus is displayed in the stand of Messrs. E. R. and F. Turner, who exhibit a good 7-horse portable engine and thrashing machine; mills of various kinds; and Ager's patent digging machine—an ingenious implement, which is said to perform its work very satisfactorily.

“Messrs. Wallis and Haslam exhibit a 4 ft. 6 in. combined thrashing machine, fitted with Coulson's spring hangers, and a hummeller resembling Underhill's elevator in its general details—the fan is not used as an elevator, however, its duties being confined to the hummelling of the grain, and the supply of a subsidiary blast for cleaning the corn. In this stand we noticed a very ingenious steam presser and plough combined, which is well-spoken of. This firm has lately purchased the patent for Lansley's single wheel steerage for drills, &c., which we recommend to the attention of agriculturists.

“We had our attention called here to a well-finished model of Wallis's patent system of raising and delivering goods one, two, three, or four hundred feet, over intervening ground or buildings, without interference with the traffic beneath; thereby saving the whole of the expense of trucking or backing, as now in use. If goods are taken from a ship's hold, or from a railway truck, to the upper floor of a granary or mill, some power by application of a strap to a rigger, is required; but for loading out, the apparatus is self-acting. The invention is partially carried out, and may be seen at work at Wallis and Thomas's flour mills, at Basingstoke, where the intervening space traversed is 160 ft., comprising a timber wharf, belonging to the London and South Western Railway Company, and a public footpath.”

We shall conclude this division by the following practical remarks on the value of “system,” and on other points connected with the erection of machinery, and workshop duties, selected from the ‘*Scientific American*.’—

ECONOMICAL ADVANTAGES OF SYSTEM.

“Persons who have noticed how work is carried on in many of our large machine-shops, cannot but wonder why it is that no established system and routine is laid down to be observed by the

workmen. The advantages of such a plan are too obvious to require any comment; and it is, as we have remarked, incredible how many things are left to take care of themselves, that should have been regularly classified, and arranged with reference to the demands of the work. Let us take, for instance, the item of mandrels, as they are called here; or arbors, as they are better known in some other parts. These valuable, and indeed indispensable aids to machine work in too many instances have no more care or attention bestowed upon them than if they were scrap-iron. They are often made of iron, instead of steel, and are cut, hacked, battered, and ground in the centres, by careless workmen, until they are utterly useless. A good mandrel costs too much money to be subjected to such usage, and this is but a small part of the evil; for where such bad practices prevail there are not likely to be good workmen, and no shop can create or maintain a reputation where such carelessness is permitted. The loss pecuniarily is to be considered also; for where there are no regulations as to mandrels or other tools, any workman makes one as he requires it, and throws it down on the floor when he is done, from whence it is perhaps snatched the next moment and used for battering some other mandrel, into, or out of a pulley.

"Such folly and wastefulness as this must and should receive the severest condemnation of every right-thinking person. System, as applied to the use of mandrels, is not the only place where it might be adopted with good results. Let us take the matter of measurement, for instance. In too many workshops the only reliance for proper fitting work is placed on an old, illegible, greasy, shaky-jointed, smooth-ended, wooden two-foot rule; which is about as useful for measuring purposes as so many inches of a broomstick. With this valuable aid, the old-fogy workman gravely takes a pair of callipers, and turns up a shaft from it to the size of 'four inches.'

ARE SCRAPED SURFACES INDISPENSABLE?

"In stating this question as broadly as we have done, we disclaim at the outset any intention of dispensing utterly with scraped surfaces, or of erasing from the vocabulary of mechanical *technicalities* this detail of the workshop. The doubt has arisen

in our mind whether much of the time and elaboration expended on scraping iron surfaces might not, without injury to the work itself, be omitted. The value of a positively correct face on a valve seat or on the V-shaped ribs of a slide lathe or planer, is undoubtedly great when it is well done, but when poorly executed the utility of it is, to say the least, questionable. We make the unqualified assertion that not one man in twenty is competent to finish a truly scraped surface. Scraping iron down to a perfect face is an art by itself, and comparatively little attention, so to speak, has been given to the subject in this country. The common method in use is to take an old file of any kind (except round or square), flatten its end out like a chisel, grind it up square on the stone, and then 'grub' away on the iron wherever the workman sees fit. The chances are that previous experience has not fitted the operative for this branch of his business, and he mistakes a shade on the iron for a bearing, and makes a depression still deeper by misapprehending the 'situation.' Of course the fallacy of attempting to make a true face in this way is manifest to every one familiar with the subject. It would have been far better to have saved the time wasted in such attempts and trust to good planing and attendance in future to rectify inaccuracies.

"The better way to make a scraper is to form it like a Venetian stiletto, or more familiarly, after the model of the section of a beech nut; that is, to have the blade triangular in section, and approaching concavity. With such an instrument, properly tempered, ground, and sharpened, the finest work can be produced. A flat-faced scraper is an abomination, and only fit to dig holes or to rough out the work for the triangular scraper; it is apt to make 'chatters' in the surface, and when these occur we may bid a long farewell to any fine work without filing them out—a very pretty task to undertake after something like accuracy has been attained. Most scraped surfaces are nothing but a combination of scratches, shining blotches, and untruth; and while they are a waste of time to execute, they add nothing to the mechanical value of the work. We may fairly question whether of *valve*-seats up to 180 square inches of area, say 15 inches by 12 inches, are benefited by scraping. In some locomotive-shops in
try it is the practice to plane the valve-seat so that the

tool-marks on it run in one direction, and place the valve so that similar marks in it cross the seat at right angles, and to set the valves running in this way without further adjustment. The results observed are that in a few days the valve has made a seat for itself that is far more durable than if it had been badly scraped. We do not go so far as some persons and assert that a scraped valve-seat is a positive injury, insomuch that the pores of the iron are filled with an impalpable dust that works out to the detriment of the engine in future; this theory is very finely drawn, although it may be partly sustained by facts. A finely-finished mirror-like surface on a valve-seat or lathe shears is indubitably of great value, and we must, in common justice, give credit to English workmen for great skill in this particular; in general they far excel our own workmen.

"There is no reason whatever to interfere with the execution of a finely-elaborated scraped surface in our own shops; but our observation convinces us that time spent in doing such work as we have seen, might be better employed in some other way.

KEYING WHEELS ON SHAFTS.

"Wheels in machines are secured to shafts by different methods, such as forcing them on, by keys, by nuts and washers; and occasionally by riveting; keys are more generally employed than any other device, being the surest way of preventing the wheel from turning, working off, or becoming loose, when the respective key-ways are well made and the key properly fitted. We have been requested by various correspondents, at different times, to inform them where they could procure a work on key-ways, one which treated of the relative proportions for different sizes of wheels and shafts, and other general particulars which the experience of the author might suggest. We do not know of any, nor do we think such a work would be likely to meet with a ready sale; besides which it would not be at all easy to lay down rules, or laws, for definite instructions in a case where so much depends upon practical knowledge. The principle of a key is that of a wedge, and it secures the wheel mainly by that force; how far the taper of the key should extend, and what *material* should be used for it, are matters which must depend

wholly upon knowledge acquired by observation. In nearly all cases steel is preferable for small keys; but in some situations soft iron is better than the former, for the reason that it affiliates, or hugs, the shaft closer than a harder and finer-grained metal would. The sea-going steamers out of this port have large keys in their paddle shaft centres, by which they are held in place. It was at one time the practice to cast the eye or hole of the centre octagonal in shape; each plane of the octagon being truly filed to a bearing; the shafts also had corresponding planes, and when the keys were driven they were placed alternately with reference to the head and point; one key being driven from the right, the next one from the opposite side. In this way the centre was keyed up truly all round; the keys were large slabs of wrought iron, from 14 to 20 inches long, by 4 inches wide, and 1 inch thick; the taper or 'draught' allowed on these was not more than $\frac{1}{10}$ th of an inch; in some cases not so much. This plan of securing paddle-wheel centres has now been measurably done away with, as it was costly and not at all reliable, so many keys being used that one took the strain off the other, and some invariably worked loose. The method now adopted is to use one, or at most two, large and heavy keys. The centre is cored out in the foundry, so that only one half of the circumference of the shaft hole has to be bored; this half is accurately bored to fit the turned boss on the shaft, and the keys are fitted to ways cut in the cored-out part of the centre; when they are driven, therefore, the bored part fits the shaft, and is forced into the closest contact with it. This plan is now generally pursued on all large steamers.

"The hold of a key depends so much upon its fit and taper that, as we have remarked, individual experience must be the guide to success; but it is not amiss to assert that very little taper is necessary, and that beyond a certain amount the tendency of it is to split the wheel and cause it to work off. The wheel should fit nicely, and then there will be still less strain required to retain it in place. In all cases gib-heads to the keys are a convenient means of drawing them out when such a course is necessary. We believe that car wheels are now pressed on, *in the very best practice*, and this will be found a good plan in *most cases* for other work. Besides being cheap, it is safe, al-

though there is always a bursting strain on the hub which tends to weaken its endurance. Seats too deep and others too shallow in the shaft and wheel are to be avoided ; the latter soon works off the corners where wheels are not well fitted, and the former makes unnecessary work and looks badly. In all cases the key must be proportioned to the work or duty the machinery is to sustain, and this proportion must be learned by observation, and an exercise of the laws of common sense.

PIECE WORK.

“There is, it appears, a general and growing inclination, all over the country, in favour of the system of ‘piece work,’ or of allowing each man to earn such wages as his skill and abilities enable him to. In favour of the plan there is much to be said, while in discouragement of it there would seem to be very little ground for objection. In the first workshops of the country the system of piece work is now very generally adopted ; and the best conducted and most prosperous establishments are invariably committed to this method of carrying on their business. In proof of this assertion we may point to the Wheeler and Wilson Sewing Machine Manufactory, to the Waltham Watch Company, and others we might name, all working by the piece. We presume no one will deny that if the piece work plan will answer in these places, there can be little doubt of its success in other branches of manufacture, which do not require as much care and constant oversight as those above mentioned. It has been asserted in condemnation of allowing operatives to work as fast as they chose, that the quality of the article produced was much inferior to that made by day work. This statement is transparently illogical, when we view the splendid work turned out by the companies enumerated, and bear in mind the competition they are subjected to. In favour of piece work it may be said that the strongest incentives are laid before the workman to exercise all the latent talent and ability he may possess. The factories in this country that produce a standard kind and quality of work, as pistols, sewing machines, &c., have special tools for the accomplishment of their objects, which tools are *run by the workmen* ; possibly they do not accomplish as much

as they might; if a certain device was applied on some part they would do double duty. The man in charge sees this, because it is for his interest to: it will increase his wages; the addition is made, sometimes at his own expense, and involving quite an outlay: for the workman is satisfied to give ten, or a hundred dollars, where he knows that he will receive a thousand in return. This is largely to the advantage of all parties—the concern and the artizans—and it is also a direct acquisition to the world of art and science. If any person wishes to inspect model machines—those that approach the nearest to human intelligence—let him visit some of our best conducted manufacturing establishments, and he will see what the system of doing work by the piece tends to encourage and develope.

“When a man is hired by the day, he gets his wages (if not notoriously idle) even if he does not accomplish nearly as much as his neighbour; but when he has a stimulant held out before him to double his task, it induces him to strain every nerve to accomplish it. We have heard it asserted that piece work tended to make men dissipated and demoralized, by the large wages they earned; that they neglected their families and became idlers, &c., but this is a very weak argument against the system. Piece work is not intended to force moral convictions upon a workman's mind; if he have not these principles instilled in early youth, he is of little value as a craftsman, either by the piece or by the day. Piece work is an acknowledgment of a man's right to earn all he can; while a certain amount of hire weekly virtually limits his capacities to the sum allowed. Men work by the day pretty much as they choose, whereas if they are awarded contracts in themselves so to speak, they are more apt to execute them faithfully and quickly. Some branches of manufacture do not admit of the introduction of such a system; while many others, that are not so conducted, would be benefited by its adoption.

CONSTRUCTION AND REPAIR.

“The life of a machine depends measurably upon two things—its construction, and the usage to which it is subjected; all others are subordinate. Admitting this, it is palpable that the

better a machine is made, the greater credit will belong to those who constructed it. But in sending away machines from the workshop as finished, mistakes and oversights are sometimes committed, that redound injuriously to the maker's reputation. Theoretically, the mechanical minutiae of the best locomotives present a model which should be emulated, and copied into other forms of mechanism all over the land. To be explicit—the closely and accurately-fitted gibs and keys in the connecting rods of locomotive engines, the neat manner in which the brasses are fitted to their several places, the tight joints, the reamed holes, and steady pins, in addition to the security derived from screw bolts, for preventing parts from shifting out of line with each other, should be more generally adopted as mechanical practice than it is. Of course, all machinery will wear out, sooner or later. Every tool has its allotted period of service; but the time of its utility may be very much lengthened by the manner in which it is put together. Cheap tools are not always cheap. They may be sold at a low price, but they are continually breaking down, and require renewing so often that the outlay upon them in a short time equals the value of a first-class article. Tools to be cheap must be well made; then they will last for years at a small expense for repair. Our steam fire engines have been praised in England, on account of their superior finish, and general excellence of workmanship; but those sent out were not by any means the finest we have, being only a sample; the 'Manhattan' in particular having been in constant use nearly four years. We cite this fact as going to show the attention everywhere paid to good workmanship; and the important bearing it has upon the reputation of the maker, and the performances of the machines themselves.

"We have been sorry to remark, in some parts of the country, a general inattention to the well-established mechanical laws and rules (not scientific, but practical ones); as, for instance, putting a $\frac{5}{8}$ bolt into an $\frac{11}{16}$ th hole; drilling holes too large which were to be tapped; putting rough bolts into reamed holes; using threads of too coarse pitch, and similar acts, professionally improper and irregular, which should not occur. We make these remarks in no captious spirit, but with an earnest desire to see our manufacturers, all over the country, avail

themselves of the skill and improvements of others; believing that by so doing they will in the most direct manner serve their own interests.

THE ABUSE OF FILES.

"There are by far too many files wasted and misused in ordinary work, and the abuse is one that should be checked at once. To judge from the treatment some persons bestow on these costly tools, they are as common as pins and about as valuable. A new file is used for fitting a Babbitt metal box to a shaft, or a file for brass-work is used alike on iron and brass; and then another must be procured when the workman desires to finish brass again. And so the interchange goes on, until the consequence is that the workman guilty of such carelessness has no file of any kind, fit for any purpose in his drawer. Hard steel makes no difference to a file-abuser either. Apparently there are some individuals who think that because a diamond will cut another diamond, so a file must bite another file; they pursue this theory and rasp away on the scale of cast-iron, or over the black places in forgings, with an utter disregard of their employers' time and money. A fifteen-inch flat bastard file costs from a dollar to a dollar and a half, but we have seen one of these tools placed *hors de combat* in five minutes by the blundering stupidity, not to say criminality, of the person using it. If the individual had been obliged to buy it himself, it is hardly to be supposed that he would have treated it in such a manner. It contributes in no wise to the reputation of any workman to be careless of tools that he uses but is not obliged to purchase, and it would be much better for all parties if a little more consideration was given to this matter."

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